S. Hrg. 100-602, Pt. 1

DEPARTMENT OF ENERGY NATIONAL LABORATORY COOPERATIVE RESEARCH INITIATIVES ACT

HEARINGS

BEFORE THE

SUBCOMMITTEE ON
ENERGY RESEARCH AND DEVELOPMENT

OF THE

COMMITTEE ON
ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

ONE HUNDREDTH CONGRESS

FIRST SESSION

ON

S. 1480

TO IMPROVE THE INTEGRATION OF UNIVERSITIES AND PRIVATE INDUSTRY INTO THE NATIONAL LABORATORY SYSTEM OF THE DEPARTMENT OF ENERGY IN ORDER TO SPEED THE DEVELOPMENT OF TECHNOLOGY IN AREAS OF SIGNIFICANT ECONOMIC POTENTIAL

SEPTEMBER 15 AND 17, 1987

PART 1

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DEPARTMENT OF ENERGY NATIONAL LABORATORY COOPERATIVE RESEARCH INITIATIVES ACT

TUESDAY, SEPTEMBER 15, 1987

U.S. Senate,
Subcommittee on Energy Research and Development,
Committee on Energy and Natural Resources,
Washington, DC.

The subcommittee met, pursuant to notice, at 2:04 p.m., in room SD-366, Dirksen Senate Office Building, Hon. Wendell H. Ford, presiding.

OPENING STATEMENT OF HON. WENDELL H. FORD, A U.S. SENATOR FROM THE STATE OF KENTUCKY

Senator **Ford**. The subcommittee will come to order.

We will proceed. The Congressman, I understand, is not here yet. I have an opening statement and two or three to file. I will do that.

I am not sure I can pronounce the Congressman's name either. I think it is Hochbrueckner. For a southern boy who likes small words, that is a little hard to do.

I am pleased to be here today to hear testimony on Senator Domenici's Senate Bill 1480 concerning research initiatives at the Department of Energy's National Laboratories. I welcome all of our distinguished witnesses this afternoon. This is the first day of hearings on this legislation. We are now scheduled to meet again on Thursday to continue this discussion.

I have always recognized the Department's National Laboratories as a significant source of information on advanced technology in the United States. This legislation enhances the role of the National Laboratories in three specific areas, superconductivity, semiconductors, and mapping of the human genome.

S. 1480 seeks to tap the expertise of the National Laboratories and establish a framework for cooperation between Federal agencies, university and medical research facilities and private enterprise toward national research goals in these three particular areas.

The Department of Energy has maintained a role in specific research in all of these areas. However, these areas are very broad and complex, and much additional information is needed. I am grateful that these hearings have been scheduled.

[The text of S. 1480 and a statement from Senator Johnston follow:]

II

100TH CONGRESS
1ST SESSION

S. 1480

To improve the integration of universities and private industry into the National Laboratory system of the Department of Energy in order to speed the development of technology in areas of significant economic potential.

IN THE SENATE OF THE UNITED STATES

JULY 10 (legislative day, JUNE 23), 1987

Mr. DOMENICI introduced the following bill; which was read twice and referred to the Committee on Energy and Natural Resources

---

A BILL

To improve the integration of universities and private industry into the National Laboratory system of the Department of Energy in order to speed the development of technology in areas of significant economic potential.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, At the end of the Federal Non-Nuclear and Energy Research and Development Act of 1974 add the following new title:

SECTION 1. SHORT TITLE.

This Act may be cited as the "Department of Energy National Laboratory Cooperative Research Initiatives Act".

SEC. 2. FINDINGS AND PURPOSE.

(a) FINDINGS AND PURPOSE.—The Congress finds that—

(1) the Department of Energy has nine multiprogram National Laboratories with missions that include general science, energy science, and defense-related technology development;

(2) these laboratories have large and complex "user facilities", uncomparable research equipment, unparalleled computer facilities, and excellent research and support staffs;

(3) while each laboratory has a technology transfer program the results have only been modest because private industry has not been sufficiently involved with the laboratories;

(4) a new, national initiative is needed to increase the flow of energy related technology from these laboratories to the private sector; and

(5) the goal of this new initiative should be to link the Nation's capabilities for generating scientific and energy related technological innovations to its capabilities for commercial activities.

(b) PURPOSE.—The purpose of this Act is to improve the integration of universities and private industry into the National Laboratory system of the Department of Energy in order to speed the development of technology in energy related areas of significant economic potential.

TITLE I—ESTABLISHMENT OF UNITED STATES INDUSTRY AND DEPARTMENT OF ENERGY LABORATORY CENTERS FOR RESEARCH ON ENABLING TECHNOLOGIES FOR HIGH-TEMPERATURE SUPERCONDUCTING APPLICATIONS

SEC. 101. FINDINGS AND PURPOSE.

(a) FINDINGS.—The Congress finds that—

(1) the Department of Energy has conducted extensive research in superconducting materials to support its programmatic activities in High Energy Physics, Magnetic Fusion Energy, Energy Storage Systems, Electric Energy Systems, and Energy Conservation pursuant to the Federal Nonnuclear Energy Research and Development Act of 1974 (Public Law 93–577), the Energy Reorganization Act of 1974 (Public Law 93–483), and the Department of Energy Organization Act (Public Law 95–91);

(2) recent developments in high-temperature superconducting materials hold great promise for highly efficient energy storage and transmission, medical diag-

nostics, magnets for physics research and fusion reactors, and smaller supercomputers;

(3) the United States is a world leader in basic research on high-temperature superconducting materials and programs supporting this research at the National Science Foundation and the Department of Energy should be maintained and strengthened;

(4) international interest in the commercialization of high-temperature superconducting materials is high and the key to success lies in the rapid development of these materials and the identification of applications; and

(5) the National Laboratories of the Department of Energy have demonstrated expertise in superconductivity research and a proven record in research in enabling technologies which can benefit industrial efforts in product development.

(b) PURPOSE.—The purposes of this title are—

(1) to research critical enabling technologies to assist United States industry in the commercialization of high-temperature superconductors;

(2) to provide national organization and coordination in the research, development, and commercialization of high-temperature superconductors; and

(3) to encourage private industry, university, and Department of Energy National Laboratory interaction through Centers for Research on Enabling Technologies at the National Laboratories.

SEC. 102. FORMATION OF COUNCIL AND CENTERS FOR RESEARCH ON ENABLING TECHNOLOGIES.

(a) COUNCIL.—The Secretary of Energy shall form a council to be known as the "Council for Research on Enabling Technologies" (hereafter in this title referred to as the "Council") which shall be composed of representatives of appropriate government agencies, universities, and industry to provide guidance in setting goals and strategies for the timely research on critical enabling technologies in high-temperature superconductors. The Council shall set guidelines for the release of the technical findings and developments made by the cooperative research centers established pursuant to subsection (b).

(b) COOPERATIVE RESEARCH CENTERS.—(1) The Secretary of Energy shall establish cooperative research centers in enabling technology for superconducting materials and applications (hereafter in this title referred to as "centers") at National Laboratories with appropriate university and private industry participants.

(2) The centers shall be located at National Laboratories which demonstrate expertise in—

(A) superconductivity research; and

(B) research in associated technologies including—

(i) thin film and bulk ceramic synthesis and processing; and

(ii) characterization of physical, chemical, and structural properties in materials.

SEC. 103. ANTITRUST MATTERS.

Each center created by the Secretary of Energy pursuant to the provisions of this title shall be considered a joint research and development venture within the meaning of section 2(a)(6) of the National Cooperative Research Act of 1984 (15 U.S.C. 4301 et seq.), for purposes of such Act.

SEC. 104. COST SHARING.

The Secretary of Energy shall seek cost sharing with participating private industries in the establishment of centers under this title.

TITLE II—MAPPING THE HUMAN GENOME

SEC. 201. FINDINGS AND PURPOSE.

(a) FINDINGS.—The Congress finds that—

(1) the Department of Energy has conducted extensive research on the human health consequences of nuclear and nonnuclear energy technologies including the consequences for human genetic material, pursuant

to the Federal Nonnuclear Energy Research and Development Act of 1974 (Public Law 93–577), the Energy Reorganization Act of 1974 (Public Law 93–438), and the Department of Energy Organization Act (Public Law 95–91).

(2) the major health and well-being of our Nation depends on the medical breakthroughs in hereditary diseases, cancer, cardiovascular disease, and the aging process that will flow from mapping the human genome;

(3) the knowledge gained, as well as the countless applications will bring economic health and physical well-being to the nation that accomplishes this goal;

(4) it is a compatible and essential part of the mission of the Department of Energy's National Laboratories to participate in research and technology development projects in mapping the human genome; and

(5) the Secretary of Energy should augment and accelerate the ongoing genetic science research of the Department of Energy.

(b) PURPOSE.—The purposes of this title are—

(1) to establish a national policy board to coordinate the activities of the various government agencies involved in generic research relevant to the mapping of the human genome; and

(2) to establish a consortium under the direction of the Secretary of Energy, made up of industry, university and other government agencies to insure that the knowledge and intellectual property resulting from cooperative research are widely disseminated among the United States companies so as to enhance applications.

SEC. 202. ESTABLISHMENT OF THE NATIONAL POLICY BOARD.

(a) ESTABLISHMENT.—There is established within the Department of Energy a national policy board to be known as the "National Policy Board on the Human Genome" (hereafter in this title referred to as the "Board").

(b) FUNCTION.—The functions of the Board shall be to—

(1) identify the components of a successful national human genome strategy;

(2) develop research and development strategies, tactics, and plans whose execution will assure United States leadership in the genome area;

(3) recommend appropriate actions that support the national strategy;

(4) evaluate the ethical considerations of the national human genome strategy; and

(5) oversee the operations of the Technical and Operational Board.

(c) MEMBERSHIP OF THE BOARD.—The membership of the Board shall consist of—

(1) the Secretary of Energy, who shall serve as Chairman;

(2) the Director of National Institutes of Health;

(3) the Secretary of Agriculture;

(4) the Director of the Office of Science and Technology Policy;

(5) the Director of the National Science Foundation;

(6) a member of the Human Genome Consortium representing private industry; and

(7) a member of the Human Genome Consortium representing the universities.

(d) ESTABLISHMENT OF THE HUMAN GENOME CONSORTIUM.—(1) The Secretary of Energy shall establish a consortium, to be known as the "Human Genome Consortium" (hereafter in this title referred to as the "Consortium"), to consist of universities, private industry, and appropriate government agencies the purpose of which shall be to—

(A) create a physical map of the human genome, consisting of a complete set of segments of the DNA, arranged in order;

(B) integrate information derived from government efforts in gene mapping into private industry;

(C) locate genes and other markers on the map;

(D) produce and distribute DNA sequences and other materials needed by the research community;

(E) develop automation and robotics techniques for large-scale DNA mapping sequencing; and

(F) establish computer facilities and develop computer data bases for the storage, retrieval, and dissemination of DNA segments, mapping, and sequence information.

(2) The Consortium shall have the following technical and operational functions:

(A) collecting and analyzing information on the needs and capabilities of industry, the Federal Government, and the scientific and research communities related to the human genome;

(B) collecting and analyzing information on the needs and capabilities of industry, the Federal Government and the scientific and research communities related to the human genome;

(C) analyzing options, establishing priorities, and recommending roles for participants in the national strategy;

(D) determining technical areas where United States biological and pharmaceutical industries are deficient relative to international competition; and

(E) establishing a technology board which shall be responsible for the management of the activities of the consortium as provided in paragraph (3).

(3) The Consortium shall establish a Technical and Operation Board which shall report to the Consortium and shall be responsible for—

(A) immediately establishing technology workshops to define technology roadmaps for the consortium;

(B) approving funding for projects carried out by the consortium;

(C) monitoring the progress of such projects; and

(D) handling the day-to-day operations of the consortium.

SEC. 203. OBJECTIVES.

(a) RESEARCH INITIATIVE.—(1) The Secretary of Energy shall initiate and carry out a cooperative program of research on—

(A) developing new techniques and improving existing methods for large-scale DNA mapping and sequencing, including the applications of automation and robotics;

(B) developing new methods for characterizing and locating genes using both computational and cloning techniques; and

(C) establishing computer facilities and developing computer data bases for the storage, retrieval and dissemination of cloning, mapping and sequence information (including cross-references to other relevant data bases). The project should improve and invent algorithyms for analyzing DNA sequences, including methods for identifying coding regions, predicting protein structures and functions, and identifying genetic regulatory sites.

(2) The Initiative shall provide for temporary exchanges of personnel between any consortium referred to in subsection (b)(1)(B) and the national laboratories of the Department of Energy that are participating in such initiative. The exchange of personnel shall be subject to such restrictions, limitations, terms, and conditions as the Secretary of Defense or the Secretary of Energy consider necessary in the interest of national security.

(b) OTHER DEPARTMENT OF ENERGY RESOURCES.—The Secretary of Energy may make available, to any department or agency of the Federal Government, and to any consortium that has entered into an agreement under this section any facilities, personnel, equipment, services, and other resources of the Department of Energy for the purpose of conducting research and development projects under the Initiative.

TITLE III—SEMICONDUCTOR TECHNOLOGY MANUFACTURING EXCELLENCE INITIATIVE

SEC. 301. FINDINGS.

Congress makes the following findings:

(1) Semiconductors and related microelectronic devices are key components in computers, telecommunications equipment, advanced defense systems, and other equipment.

(2) Aggregate sales of such equipment, in excess of $230,000,000,000 annually, comprise a significant portion of the gross national product of the United States.

(3) The leadership position of the United States in advanced technology is threatened by (A) competition from foreign businesses which is promoted and facilitated by the increasingly active involvement of foreign governments, and (B) other changes in the nature of foreign competition.

(4) The principal cause of the relative shift in strength of the United States and its semiconductor competitors is the establishment of a long-term goal by a major foreign competitor to achieve world superiority in semiconductor research and manufacturing technology and the pursuit of such goal by that competitor by

effectively marshalling all of the government, industry, and academic resources needed to achieve that goal.

(5) Although the United States semiconductor industry has invested 83 percent of its aggregate pretax profits in research and development and leads all other major United States industries in the percentage of pretax profits invested in research and development, such level of investment has been insufficient when judged by worldwide standards.

(6) Electronic equipment is essential to protect the national security of the United States, as is evidenced by the allocation of approximately 35 percent of the total research, development, and procurement budgets of the Department of Defense to electronics research.

(7) The Armed Forces of the United States will eventually depend extensively on foreign semiconductor technology unless significant steps are taken, and taken at an early date, to retain United States leadership in semiconductor technology research.

(8) It is in the interests of the national security and national economy of the United States for the United States to regain its traditional world leadership in the field of semiconductors.

(9) The most effective means of regaining that leadership is through a joint research effort of the Federal Government and private industry of the United States to improve semiconductor manufacturing technology and to develop practical uses for such technology.

(10) In order to meet the national defense needs of the United States and to insure the continued vitality of a commercial manufacturing base in the United States, it is essential that priority be given to the development, demonstration, and advancement of the semiconductor technology base in the United States.

(11) The national laboratories of the Department of Energy are a major national research resource, and the extensive involvement of such laboratories in the semiconductor research initiatives of the Federal Government and private industry would be an effective use of such laboratories and would help insure the success of such initiatives.

(12) It is vital to the interests of the United States that semiconductor technology developed as a result of the semiconductor research and development program established under this title be used exclusively by the United States semiconductor industry.

SEC. 302. SEMICONDUCTOR TECHNOLOGY MANUFACTURING EXCELLENCE INITIATIVE.

(a) ESTABLISHMENT OF INITIATIVE PROGRAM.—The Secretary of Defense shall initiate and carry out a cooperative program of research on semiconductor manufacturing technology and on the practical applications of such technology (such program hereinafter in this title referred to as the "Initiative"). The Secretary shall carry out such program in conjunction and coordination with—

(1) the Department of Energy and such other departments and agencies of the Federal Government as the Secretary of Defense determines appropriate for participation in such program; and

(2) any consortium which—

(A) is comprised of representatives of the semiconductor industry in the United States;

(B) is selected by the Secretary to participate in the program; and

(C) enters into an agreement with the Secretary to participate in the program.

(b) PROGRAM FEATURES..—The Initiative—

(1) shall be designed—

(A) to simulate increased development of semiconductor manufacturing technology in the

United States and to stimulate development of new applications of such technology for various industries; and

(B) to promote research on and development of materials, devices, and manufacturing infrastructure for the production of semiconductors;

(2) shall include provisions for the consortium referred to in subsection (a)(2)—

(A) to conduct research on and development of advanced semiconductors manufacturing techniques, including techniques relating to submicron lithography, desposition, advanced materials, etching, cleaning and epitaxy, silicon process integration, and compound semiconductors and devices for use in optoelectronics and optical communication;

(B) to carry out tests and demonstrations of such techniques on production lines;

(C) to develop variations of such techniques, after testing and demonstrations confirm the usefulness of such techniques, in order to promote the use of such techniques for manufacturing a variety of products; and

(D) to develop an automated and integrated process which could be used in the high volume manufacture of a variety of products; and

(3) shall include provisions for national of laboratories for the Department of Energy to conduct activities described in section 303(c).

SEC. 303. INVOLVEMENT OF NATIONAL LABORATORIES OF THE DEPARTMENT OF ENERGY.

(a) IN GENERAL.—The Secretary of Defense, in consultation and coordination with the Secretary of Energy, shall ensure that the national laboratories of the Department of Energy participate in the Initiative.

(b) MISSION OF NATIONAL LABORATORIES OF THE DEPARTMENT OF ENERGY TO PARTICIPATE IN INITIATIVE.—(1) It shall be an essential part of the mission of each national laboratory of the Department of Energy to participate in research and devlopment projects under the Initiative in conjunction with the Department of Defense and any consortium referred to in section 302(a)(2), including any college or university carrying out any such project for or in cooperation with the consortium under such initiative.

(2) The Secretary of Energy shall enter into such agreements with the Secretary of Defense, with any consortium referred to in section 302(a)(2), and with any college or university referred to in paragraph (1) as may be necessary to

provide for the active participation of the national laboratories of the Department of Energy in the Initiative.

(c) WORK PROGRAM OF NATIONAL LABORATORIES OF THE DEPARTMENT OF ENERGY.—The Initiative shall include provisions for one or more national laboratories of the Department of Energy, in conjunction with any consortium referred to in section 302(a)(2), to conduct research and development activities relating to silicon and compound semiconductors, including research on and development of such advanced semiconductors manufacturing technologies as ultra clean processing, processing for ultra-high-density silicon circuits, and improved compound semiconductors and devices. Such activities may include research and development relating to materials fabrication, materials characterization, design and modeling of devices, and new processing equipment.

(d) PERSONNEL EXCHANGES.—The Initiative shall include provisions for temporary exchanges of personnel between any consortium referred to in section 302(a)(2) and the national laboratories of the Department of Energy that are participating in such initiative. The exchange of personnel shall be subject to such restrictions, limitations, terms, and conditions as the Secretary of Defense or the Secretary of Energy consider necessary in the interest of national security.

SEC. 304. OTHER DEPARTMENT OF ENERGY RESOURCES.

(a) IN GENERAL.—The Secretary of Energy may make available to the Department of Defense, to any other department or agency of the Federal Government, and to any consortium that has entered into an agreement under this title any facilities, personnel, equipment, services, and other resources of the Department of Energy for the purpose of conducting research and development projects under the Initiative.

(b) BUDGETING FOR SEMICONDUCTOR TECHNOLOGY RESEARCH.—The Secretary of Energy, in preparing the research and development budget of the Department of Energy to be included in the annual budget submitted to Congress by the President under section 1150(a) of title 31, United States Code, shall provide for programs, projects, and activities that encourage the development of new technology in the field of semiconductors.

SEC. 305. COOPERATIVE RESEARCH AND DEVELOPMENT AGREEMENTS AT NATIONAL LABORATORIES OF THE DEPARTMENT OF ENERGY.

(a) AUTHORITY OF A CONTRACTOR OPERATING A NATIONAL LABORATORY.—Any contractor operating a national laboratory of the Department of Energy that is participating in the Initiative may exercise, subject to the provisions of this section, the same authority with respect to research and development under such initiative as may be exercised by Government-operated Federal laboratories under section 11 of the Stevenson-Wydler Technology Innovation Act of 1980 (15 U.S.C. 3710a). The authority provided under this subsection includes the authority to make agreements relating to intellectual property rights in any semiconductor technology or device developed by an employee of such contractor.

(b) Cost-Sharing Agreements.—The director of each national laboratory of the Department of Energy that is participating in the Initiative or the contractor operating any such national laboratory may include in any cooperative research and development agreement entered into with a domestic firm in connection with such initiative a requirement for the Department of Energy to pay a portion of the cost of the research and development activities carried out by that firm under such initiative. The Department of Energy's share of such cost shall be determined on the basis of such cost-sharing arrangement as may be agreed upon by the director or contractor and a representative of such firm and shall be specified in the agreement.

(c) Agreements Not Subject to Approval by the Head of an Agency of the Federal Government.—Subject to subsection (d), no cooperative research and development agreement entered into under subsection (b) shall be subject to prior approval by the Secretary of Energy or the head of any other department or agency of the Federal Government.

(d) LIMITATIONS ON OBLIGATIONS OF THE DEPARTMENT OF ENERGY.—(1) No Department of Energy National Laboratory may receive more than $10,000,000 of non-appropriated funds under any cooperative research and development agreements entered into under this section in connection with the Initiative except to the extent approved in advance by the Secretary of Energy.

(2) Not more than the amount equal to 5 percent of any National Laboratory's annual budget shall be received from non-appropriated funds under the Initiative in any fiscal year except to the extent approved in advance by the Secretary of Energy.

SEC. 306. AVOIDANCE OF DUPLICATION.

In carrying out the Initiative, the Secretary of Defense shall ensure that unnecessarily duplicative research is not performed at the research facilities (including the national laboratories of the Department of Energy) that are participating in such initiative.

SEC. 307. ADVISORY COMMITTEE.

(a) ESTABLISHMENT AND RESPONSIBILITIES.—The Secretary of Energy shall establish an advisory committee which shall advise the Secretary on the following matters:

(1) Effective utilization of the facilities and technical personnel at the national laboratories of the Department of Energy in connection with the Initiative.

(2) How to avoid waste in utilizing such facilities and personnel in such Initiative.

(3) How to minimize the duplication of effort between the research and development activities undertaken at such national laboratories and similar research and development activities undertaken by the Department of Defense.

(b) SIZE OF THE ADVISORY COMMITTEE.—The Secretary of Energy shall determine the number of members of such advisory committee.

(c) APPOINTMENT AND QUALIFICATIONS OF MEMBERS.—The members of such advisory committee shall be appointed by the Secretary of Energy from among persons employed by the national laboratories of the Department of Energy, persons employed by the United States semiconductor industry or semiconductor technology trade associations, and persons involved in semiconductor research activities at colleges and universities in the United States.

(d) TERM OF OFFICE; REAPPOINTMENTS.—Each member of such advisory committee shall be appointed for such term as the Secretary of Energy shall prescribe, but no member may be appointed for a term longer than 2 years. A member may be reappointed for one or more successive terms. A member who is reappointed shall be reappointed for a term equal to the term of the member's original appointment.

(e) MEETINGS.—The advisory committee shall meet at least 4 times annually at locations to be selected by a majority of the members of the Committee.

(f) COMPENSATION PROHIBITED.—No compensation may be paid to the members of such advisory committee for service on the advisory committee.

(g) TRAVEL EXPENSES.—The Secretary of Energy shall reimburse members of such advisory committee for travel expenses, including per diem in lieu of subsistence, at rates authorized for employees of agencies under subchapter I of chapter 57 of title 5, United States Code, while away from their homes or regular places of business in the performance of services for the advisory committee.

(h) COMMITTEE EXPENSES.—The expenses of such advisory committee shall be paid out of funds available to the Secretary of Energy.

(i) INAPPLICABILITY OF TERMINATION PROVISION IN THE FEDERAL ADVISORY COMMITTEE ACT.—Section 14 of the Federal Advisory Committee Act (5 U.S.C. App. 2) shall not apply to the advisory committee established under subsection (a).

SEC. 308. RELATIONSHIP TO OTHER LAWS.

Section 152 of the Atomic Energy Act of 1954 (42 U.S.C. 2182), section 9 of the Federal Nonnuclear Energy Research and Development Act of 1974 (42 U.S.C. 5908), any other provision of law that provides for intellectual property rights in a manner inconsistent with section 406, or any other provision of law that provides for cooperative research and development agreements in a manner inconsistent with section 405 shall not apply with respect to the Initiative.

SEC. 309. LIMITATION ON FEDERAL SHARE.

Not more than 50 percent of the cost of the Semiconductor Research Initiative may be paid for with Federal funds.

SEC. 310. AUTHORIZATION OF APPROPRIATIONS.

(a) In General.—There is authorized to be appropriated to the Department of Energy for fiscal year 1988, fiscal year 1989, and fiscal year 1990 the sum of $25,000,000 for the activities of the Department of Energy under the Initiative.

(b) Relationship to Funds Available to the Department of Defense.—Funds expended by the Secretary of Energy in connection with activities f the Department of Energy under the Initiative shall be in addition to amounts available to the Department of Defense for semiconductor manufacturing technology research and development.

SEC. 311. DEFINITIONS.

In this title:

(1) The term "domestic firm" means any business entity which is not a foreign firm.

(2) The term "foreign firm" means a business entity owned or controlled by one or more foreign nationals or a business entity in which more than 50 percent of the voting stock is owned or controlled by one or more foreign nationals.

(3) The term "funding agreement" means any contract, grant, or cooperative agreement entered into between the Secretary of Energy and a contractor operating a national laboratory of the Department of Energy that provides for such contractor to perform research and development at such national laboratory.

TITLE IV—INSTITUTE FOR ENTREPRENEURIAL STUDIES

SEC. 401. FINDINGS AND PURPOSE.

(a) FINDINGS.—The Congress finds that—

(1) science and technology are critical to our country's future especially since competitor nations are investing heavily to improving their capabilities in this area; if our Nation is to remain in the competition, our Government must make a capital investment to enhance its science and technology capabilities;

(2) established companies and entrepreneurs can no longer keep pace with the rate technology is developing;

(3) restoring our competitiveness requires a Federal commitment to promote and foster research and entrepreneurial skills that will improve cooperative linkages between scientists, engineers, and industry;

(4) the National Laboratories Industry University partnership is fundamental to meeting these goals of fostering entrepreneurial superiority that will lead to economic competitiveness;

(5) a new generation of entrepreneurs is needed to properly take advantage of today's dynamic environment of technological innovation; and

(6) along with its specific areas of scientific research, the Department of Energy can contribute to economic competitiveness by establishing regional institutes of entrepreneurship chartered as work-study programs.

(b) PURPOSE.—The purpose of this title is to establish within existing universities, six regional Institutes for Entrepreneurial Studies chartered as work-study programs that would be affiliated with a Department of Energy National Laboratory.

SEC. 402. ESTABLISHMENT OF INSTITUTES FOR ENTREPRENEURIAL STUDIES.

(a) ESTABLISHMENT.—The Secretary of Energy shall establish six regional Institutes for Entrepreneurial Studies at six universities, each with an association with one of the National Laboratories, which shall conduct work-study programs for students in accordance with this title.

(b) SELECTION OF UNIVERSITIES.—The Secretary of Energy shall select the universities under subsection (a) based upon—

(1) the quality of the research and development being carried out at the university;

(2) the degree of commercialization potential for such innovative research and development;

(3) regional and geographic distribution of funds to insure Institutes throughout the States and regions of the country; and

(4) the economic stimulus to a State or region derived from the research and development.

(c) GOVERNING BOARD.—The Secretary of Energy shall establish a Governing Board of the Institutes of Entrepreneurial Studies to be composed of representatives of appropriate government agencies, universities, and industry. The function of the governing board shall be to coordinate and direct the activities of the Institutes for Entrepreneurial Studies.

SEC. 403. PROGRAM OF STUDY AT INSTITUTES FOR ENTREPRENEURIAL STUDIES.

The program of study for each student at an Institute for Entrepreneurial Study shall be established as follows:

(1) Each student shall pursue a specific project during their course of study.

(2) The curriculum for each student shall include—

(A) development and writing a business plan and establishment of a corporate structure;

(B) venture capital;

(C) management of technology, technologists, and technological change;

(D) international markets and competition;

(E) marketing and market reserve;

(F) manufacturing;

(G) licensing and intellectual property rights;

(H) crisis management; and

(I) ethics.

(3) Each student shall work on a specific project with the assistance of a mentor in one of the National Laboratories or private industry.

(4) A masters degree shall be available to students, however, candidates shall not be required to pursue a masters degree.

SEC. 404. AUTHORIZATION.

There are authorized to be appropriated such sums as are necessary to carry out the provisions of this title.

STATEMENT OF HON. J. BENNETT JOHNSTON, A U.S. SENATOR FROM THE STATE OF LOUISIANA

I congratulate Senator Domenici for this legislation and Senator Ford for holding these hearings.

Senator Domenici's bill, the Department of Energy National Laboratory Cooperative Research Initiatives Act, taken together with the amendments to the bill that Senator Domenici introduced on July 10, would make very significant changes in the way the DOE National Laboratories and the private sector carry out research and development in superconductivity, semiconductor manufacturing techniques, and the mapping of the human genome.

These changes are directed at the weakest point in our system for developing technology: the transition from the laboratory to commercialization. The scientific establishment of the United States has been a tremendous source of new ideas, techniques and devices for the world. But we have not been as successful in commercializing what we have developed. That has been the specialty of the Japanese and, to a lesser extent, the Europeans.

The combination of U.S. ideas and the manufacturing and organizing skills of the Japanese has made the world a richer place. But most of the wealth went to the Japanese. The examples are familiar: electronics, automobiles, solar photovoltaics. We do the basic science. The Japanese commercialize it.

We now have before us a number of scientific developments of particularly significant potential. The point of this legislation is to influence the commercialization of three of the most important of these. It is very appropriate that the question of commercialization should be raised in connection with these developments. Let me discuss one such development that is a topic for this hearing: High-temperature superconductors.

High-temperature superconductors could—and almost certainly will—change our lives in very fundamental ways. Probably the biggest question is how soon the changes will occur.

High-temperature superconductors could lead to compact computers of tremendous ability. With small, but very powerful, computers a new generation of automated devices would be in reach. Effects would be felt, for example, in our ability to explore the solar system, to preserve the environment, to educate.

High-temperature superconductors could lead to magnetically levitated transportation, breaking the linkage between transportation and liquid fossil fuels. Currently, that link is a link to oil. It drives our whole energy policy. With commercial high-temperature superconductors the driving principle of energy policy could be totally changed. So could the linkage between energy policy, the mideast, and foreign policy.

High-temperature superconductors could lead to the storage of electric energy just like we now store coal, wood or gasoline. The possibility that electric energy could be produced for later use would transform the structure of the electric utility industry. It could be the break that solar energy needs to become a significant contributor to electricity production.

So it is quite appropriate that S. 1480 should focus on high-temperature superconductivity.

The bill also aims at changing the environment for research, development and commercialization of semiconductor manufacturing techniques and genetic mapping technology.

The changes proposed by the bill and the amendments would—

Require a reluctant administration to back up its talk with action by establishing consortia involving private firms, universities and the DOE National Laboratories to facilitate commercialization of these technologies; modify the federal rules governing intellectual property, such as copyrights and patents, to encourage earlier and wider participation by the private sector in the development of these technologies; and provide new flexibility to the DOE National Laboratories to negotiate new arrangements with the private sector.

These are serious and significant proposals and deserve thorough review and debate in the committee. I am looking forward to the record of this hearing.

Senator FORD. So let's get started. We will have several witnesses today. All of the witnesses have been given five minutes to present their oral remarks, and I would like to stick to that framework so as to provide adequate time for questions if we may.

We will start with our first witness.

Has the Congressman arrived yet?

If not, Dr. Richard Rowberg, Office of Science Policy, Congressional Research Service, Library of Congress.

Doctor, welcome to the hearing, and you may proceed. If you will announce your associate, we will go from there.

STATEMENT OF DR. RICHARD E. ROWBERG, CHIEF, SCIENCE POLICY RESEARCH DIVISION, CONGRESSIONAL RESEARCH SERVICE, LIBRARY OF CONGRESS, ACCOMPANIED BY LEONARD KRUGER, ANALYST IN SCIENCE AND TECHNOLOGY, CONGRESSIONAL RESEARCH SERVICE

Dr. **Rowberg**. Thank you, Mr. Chairman. It is an honor to be here today.

With me is Len Kruger, Analyst in Science and Technology at CRS. He has been working with me in analyzing superconductivity issues.

With your permission, I will summarize my remarks and submit the written testimony.

Senator **Ford**. Your full statement will be included in the record as submitted.

Dr. **Rowberg**. Recent discoveries of materials that are superconducting at temperatures much higher than previously known raises the possibility of widespread applications with substantial economic benefits over the next several decades. A number of serious problems remain, however, before these benefits can be realized, and important questions about how to proceed need to be addressed.

The potential applications of superconductivity are vast. Over the last 20 years considerable progress has been made developing many large and small scale applications of superconductivity in both the civilian and defense areas. Despite this extensive work, commercial successes have been limited by a number of factors. Foremost are those connected with the liquid helium needed to reach the very low temperatures required for metallic superconductors. While researchers have become quite adept at using liquid helium over the last few decades, it is costly and difficult to handle.

Superconducting materials that use coolants such as liquid nitrogen, which are cheaper and more forgiving than liquid helium, would make applications of superconductivity much more attractive. For this reason, discoveries of high temperature superconductors created considerable excitement.

There are problems, however, with these new materials. First, they must be able to carry much larger electrical currents than they now can without losing their superconductivity.

Second, since they are ceramics, they are not easily formed into shapes needed for applications such as wires and thin films.

To address these and other problems an expanded research and development effort is necessary. These R&D efforts should focus on three areas.

First, the search should continue for higher temperature superconductors and for a better understanding of how these materials work.

Second, the ceramic material must be made capable of being formed into wires, tapes and thin films.

Finally, additional R&D on applications which use existing technology would help provide the knowledge needed for routine operation of superconducting systems.

The promise of the recent discoveries, coupled with the nation's concern about future economic growth and foreign competition, have prompted calls for a concerted Federal effort to develop rapidly the new technology. One result has been an upsurge in research funding in recent months by both the government and private sector. In addition to greater research funding, other measures are being proposed.

In assessing these proposals there are important points to be considered. First, should the government play an expanded role. The vigor with which many companies are pursuing the development of superconducting materials suggests that the private sector may not need much additional help, although this may only be true for electronic applications.

Next, if a greater Federal role is needed to ensure timely and effective technology development for all likely applications, then we need to consider the approach. One possibility may be to designate an existing National Lab to carry out most or all of the Federal civilian R&D efforts and to be responsible for cooperative research projects among industry, universities and government.

An alternative approach would be several cooperative projects carried out or managed by different facilities and coordinated by one Federal agency.

Finally, we also should consider the potential for greater international collaboration. Given the intensity with which other countries are pursuing high temperature superconductors, this path may be the most efficient way to exploit these new discoveries.

The promise of the new superconducting materials is vast, particularly if a superconductor is found that does not require external cooling. Despite the rapid advances seen thus far, fulfilling this promise will take several years. The difficult problems that remain to be solved and the long term economic potential, however, lend urgency to beginning efforts that will best allow this nation to benefit from these exciting and promising discoveries.

Thank you. That concludes my statement. I will be glad to answer any questions.

[The prepared statement of Dr. Rowberg follows:]

Testimony of Richard E. Rowberg
Chief, Science Policy Research Division
Congressional Research Service
Before the Subcommittee on Energy Research and Development
Senate Committee on Energy and Natural Resources

September 15, 1987

Superconductivity -- An Overview

My name is Richard Rowberg and I am Chief of the Science Policy Research Division of the Congressional Research Service. With me today is Lennard Kruger, Analyst in Science and Technology at CRS and co-author of a recent CRS report on superconductivity. My testimony, which is based on this report, presents an overview of superconductivity, including recent developments, existing and potential applications, research and development needs, and policy considerations.

Recent discoveries of materials that are superconducting, i.e., capable of conducting electricity with no resistance, at temperatures much higher than previously known raises the possibility of greater application of superconductivity with substantial economic benefits over the next several decades. If the materials can be made to carry electric current levels needed for most applications and can be fabricated easily into usable shapes -- e.g., wires and tapes -- superconducting electromagnets, power generators, power transmission cables and electronic devices are possible which operate at less cost and with much less engineering complexity than with existing technology. Many observers have expressed concern, however, that other countries, particularly Japan, will take the lead in developing these technologies and exploiting their potential, leaving the United States at an economic disadvantage if the United States does not soon take effective action.

SCIENTIFIC BACKGROUND

Superconductivity was discovered in 1911 when the Dutch physicist, Kammerlingh Onnes, found that mercury lost all electrical resistance when cooled by immersion in liquid helium to 4.2 Kelvin (K) (equal to -452 F). A temperature at which the material becomes superconducting is called its transition temperature. The absence of resistance means that no electric power is needed to maintain an electric current, and there are no energy losses as exist in conventional electrical devices. Kammerlingh Onnes was not able to exploit this discovery, however, because of other characteristics which caused the superconductivity to disappear when a small magnetic field was created. Discoveries in the 1930s uncovered materials that had higher transition temperatures and remained superconducting under more stringent conditions, but practical devices still eluded researchers. In the 1950s, a theory was developed that explained superconductivity although the theory was not able to predict materials that would have higher transition temperatures. In the 1960s metallic superconducting materials were discovered that could operate under conditions required for most applications (electromagnets, electronics, electric motors, etc.). Transition temperatures of these new materials were still low, about 18 K to 23 K (-427 F to -418 F), which meant that liquid helium was still required as the coolant. These metallic superconductors, however, stimulated considerable worldwide activity in applications research that continued to the recent discoveries of high temperature superconductors.

In 1986, scientists at IBM discovered a ceramic compound that had a transition temperature of 30 K. Although this material still required liquid helium to achieve a superconducting state, the discovery was a major increase in the transition temperature. More importantly, this finding quickly opened the door to discoveries of compounds with higher transition temperatures. In

January 1987, a compound that was superconducting at 94 K (-364 F) was produced. This discovery was significant because this temperature could be reached by liquid nitrogen which is much cheaper and easier to handle than liquid helium. Therefore, if this material could be developed into a useful form, such as a wire or tape, the complexity and cost of cooling requirements would be greatly reduced. Since then, there have been announcements of ceramic materials showing indications of superconductivity as high as 300 K (about 79 F). These latter observations are not always reproducible or appear in only part of the sample material. Recently, however, researchers have been able to isolate those portions of the sample that do become superconducting at these high temperatures. This step may allow researchers to determine the special properties that allow superconductivity and construct bulk materials that will remain superconducting at these high temperatures. The highest temperature so far where all aspects have been seen is 225 K (about -45 F), although these results are not firm. The importance of the findings nearing 300 K is the possibility of superconductivity without any external coolant, a so-called room temperature superconductor. Such a development would result in a reduction in cost and engineering complexity for any application that would be considerably greater than that which could be achieved by going from liquid helium to liquid nitrogen. It is this prospect that is most appealing for the new, high temperature superconductors.

Despite the excitement and promise of these recent discoveries, there are difficult problems that must be overcome before these new superconductors become a commercial technology. Foremost is that they must be able to carry large electrical currents without losing their superconductivity. To date, current densities (current per unit area of cross section) have been much lower than needed for nearly all practical applications, although IBM has achieved high current densities for certain ceramics in the shape of thin films. Second, ceramics are hard, brittle materials not easily formed into shapes needed for applications such as wires and thin films. It will be necessary to determine how to process these materials into such shapes in a relatively straightforward manner if widespread use of these materials is to take place. It is not yet certain that this goal can be reached, although advances are being made in a number of labs. In addition, inexpensive manufacturing technologies will have to be developed so that the desired shapes and applications can be made on a large scale.

APPLICATIONS

The potential applications of superconductivity are vast. Since the mid-1960s engineers and scientists in the United States, Europe, and Japan have made use of metallic (low temperature) superconductors in applications ranging from large electromagnets and electric power generators to very small microelectronic circuits.

The most successful application has probably been superconducting electromagnets, which take advantage of the very large current that can be carried by superconductors with virtually no power requirements. Superconducting electromagnets are used in many scientific labs in devices such as controlled fusion experiments and large, particle accelerators. The high-energy physics accelerator at the Fermilab has been using superconducting electromagnets since 1983 and the proposed superconducting supercollider would use nearly 10,000 such magnets. In addition, over 600 are in commercial use in magnetic resonance imaging medical diagnostic devices. Also, very large superconducting electromagnets are proposed for electric energy storage and tests have been run on such a device by the Electric Power Research Institute on the Bonneville electric power system. A limitation on superconducting electromagnets is the strength of the materials forming the structure of the electromagnet and the conductors themselves. The intense magnetic fields that can be generated by superconducting electromagnets create enormous forces. The ability to maintain the magnet's structure and prevent movement of the conductors in the face of these forces, ultimately limit the size of the magnetic field.

Superconducting electric power generators also have been built at Westinghouse and MIT, although not yet on the scale required by an electric utility. In addition to a slight increase in overall efficiency -- from about 98.5 percent for conventional machines to about 99.5 percent for superconducting machines -- a superconducting generator would be much smaller for a given power rating than a conventional generator. This size reduction results from the much higher magnetic fields that can be generated by superconducting electromagnets compared to a comparably sized conventional magnet. The superconducting generator's rotating electromagnet (coil) can be made much smaller and the iron that is normally needed to concentrate the magnetic field in a conventional generator can be eliminated in the superconducting version. Considerable engineering complexity is introduced, however, by the necessity of providing liquid helium cooling to the rotating coil in the generator. In addition to electric power applications, since 1970, the Navy has been building and designing superconducting motors and generators for ship propulsion. Successful test runs have been made of a 400 horsepower motor.

Another large scale application is electric power transmission. Successful development of a prototype superconducting electric power transmission cable has taken place at Brookhaven National Lab. Such cables have very large power handling capacities although only a small gain in energy efficiency because of the energy requirements of the liquid helium refrigeration system. Superconducting cables would be buried underground which would add to the relative cost of these systems compared to conventional, overhead cables. In addition, superconducting power cables need to deal with the difficult technical problems of making transitions between the superconducting portion of the system and the conventional conducting portion at the terminus of the power cable, and in being able to handle electrical disturbances that could cause superconductivity to disappear.

Small scale applications are also possible. In 1962, a superconducting device, called the Josephson junction, was discovered that raised the possibility of very high speed computers with virtually no power use. These junctions could be switched on and off to provide the same kind of electronic control as a transistor does in a conventional computer circuit. In addition, the junctions could carry out this switching several times faster than a conventional circuit. There are very difficult fabrication problems with using these junctions, however, which are compounded by the need for liquid helium cooling. In addition, constraints forced by the particular circuit designs required to make use of these junctions as elements of a computer combined with advances in conventional transistor technology have nearly halted work in the U.S. on Josephson junction computers, although work continues in Japan. Despite these problems, the Josephson junction has found application in electronic instrumentation designed to measure extremely low electric and magnetic signals such as magnetic pulses from the brain and low level infrared radiation.

In the defense area, several possible applications have received attention over the past several years. In addition to their use for ship propulsion, superconducting generators have been designed for compact electric power supply such as may be needed aboard aircraft. Compact, energy storage electromagnets to drive directed energy weapons and rail guns also would be possible. These electromagnets would release their energy in very short time periods yielding enormous power levels. Superconducting microwave systems which allow very large microwave power levels, are being developed to drive free electron lasers which are the major candidate for directed energy weapons. Such superconducting microwave systems could also be used in electronic warfare. Another example is low-level infrared detectors as sensing devices to locate enemy weapons. Such applications produce extreme selectivity in discriminating between various heat sources.

Despite the extensive work on superconductivity applications, success to date has been limited by a number of factors. Foremost are the high operating costs and technical complexity of using liquid helium as the coolant, although operating experience has shown that liquid helium can be handled with sufficient care. In addition, as discussed above, other problems exist which would occur regardless of the type of cooling used or whether external cooling were needed at all. For example the necessity of protecting against electrical disturbances and the circuit requirements of Josephson junctions are two such problems that are independent of the type of cooling required. Nevertheless, the development of materials that can use cheaper coolants (or ideally, none at all), would certainly make applications of superconductivity much more attractive. While the capital costs of these systems might not drop -- indeed it could increase depending on the ultimate cost of ceramic high temperature superconductors -- the operating costs would surely drop. Further the systems would be more forgiving to problems with the refrigeration if liquid nitrogen could be used. Of course, if no cooling were needed the systems may not be much more complicated to operate than conventional systems.

RESEARCH AND DEVELOPMENT NEEDS

The discussion presented so far points out three principal research and development objectives if we hope to realize the promise of these new superconducting materials. First is basic research to find higher temperature superconductors and to gain a better understanding of how these new materials work. These objectives are the primary target of much of the current activity both in the United States and abroad. A principal focus of this work is to find out why some materials display near-room temperature superconductivity in only part of the sample and why such behavior often is not reproducible. Another goal of this phase is to determine the factors that control the amount of current that can be carried by the high-temperature ceramic superconductors. Until the current carrying capacity of these materials is increased by factors of ten to one hundred or more, their applications will be severely limited.

The second objective is to improve the usefulness of the new high temperature materials. As ceramics these high temperature superconductors are difficult to shape and fabricate. Research and development is needed to form these materials into wires, tapes and thin films, all of which are needed for various applications. In addition, the shapes need to be flexible or easily fabricated into the particular application. For applications in electromagnets and generators, the materials need to be strong in order to accommodate the enormous forces that will be generated by the intense magnetic fields. Also, the materials must be chemically stable and relatively insensitive to corrosion resulting from contact with the environment. Without these latter characteristics, applications using these new materials would be hampered by the need to provide protective coverings.

In addition to the materials properties themselves, processing and manufacturing techniques will need to be developed that are reliable and of low cost. Such techniques are important for producing wires, tapes and films from the high temperature materials as well as manufacturing the superconducting devices themselves. Obviously, superconductors which would need no external cooling would greatly ease the manufacturing of these devices.

The final objective is to develop greater facility with the various applications that have been under development for some time and to pursue new applications that may be made possible by the new, high temperature superconductors. Most of the research on applications begun in the 1960s has wound down in the past few years. Much valuable experience and knowledge about building and operating superconducting systems, however, has been obtained. These efforts should be continued even though the new high temperature materials are not yet ready and this applications research and development activity will require liquid helium cooled technology for sometime to come. It is important to solve those problems with superconducting applications -- some of which are described above -- that are not connected with the kind of external cooling that may be needed. Also, it will be important to gain further operating experience with large scale superconducting systems even with liquid helium technology. A switch to liquid nitrogen or the elimination of any need for cooling, while certainly easing operations, will not change much of the fundamental behavior of a superconducting devices. And, the operating experience gained in this manner should speed the introduction of superconducting devices into electric power systems, computer systems, weapons systems and other systems where these devices are likely to find application.

Research and development on applications under development with metallic, low-temperature superconductors, however, must be carefully structured to allow a rapid and smooth transition to high temperature superconductors when and if the materials become available for devices. In other words, as high temperature wires and tapes with sufficient current carrying capacity become available, a well designed applications program should be able to replace existing technology with the high temperature superconductors without major disruption of the program. For this reason, the applications R&D should work closely with the materials development in order to help direct the latter research effort toward the most productive path.

POLICY CONSIDERATIONS

The promise of the recent discoveries coupled with the nation's concern about future economic growth and foreign competition in developing new technologies and products have prompted calls for a concerted Federal effort to develop the new superconducting technology very rapidly. In particular, the Japanese have formed a joint government-industry committee to direct research and will establish a center for testing and application of the new materials. Their actions have raised the concern that the United States will see another country dominate the commercial application of these high temperature superconductors. One result of this concern has been the upsurge in research funding in recent months by both the government and private sectors. Research on superconductivity has long been supported by the Federal government including the National Science Foundations, the Department of Energy, the Department of Defense, the National Bureau of Standards and NASA, although funding was declining prior to 1987. The reasons for the decline were decreasing economic prospects for potential applications -- particularly in the electric power field -- and difficult technical problems. From a low of about ten million dollars in 1986, Federal funding has grown to about $32 million, all by reprogramming. A considerable increase is expected in the coming fiscal year.

In addition to greater research funding, other measures are being proposed to accelerate United States efforts to develop and exploit high temperature superconductors. The Administration recently announced an 11-point Superconductivity initiative and several bills have been introduced in Congress. These measures emphasize coordination of research and development within the Federal government. Some designate a lead agency. Another commonality is a strong focus on technology development; in other words providing resources to develop the technology of high temperature superconductors to a point close to commercial readiness.

In assessing these proposals, there are several points that might be considered. The first question is whether the government needs to play an expanded role if the new high temperature superconductors are to find their way into commercial applications. The vigor with which companies such as IBM, AT&T, DuPont and a host of smaller companies are pursuing the development of superconducting materials appears to support the contention that the private sector will not need additional help. Further, the larger companies may possess resources to carry through development of these materials, at least as far as electronic applications are concerned. Federal funding of research into the physics and materials science of the new materials, however, will likely be a strong supplement to the industrial efforts.

Timely and effective technology development may require a more concerted, planned effort. If a lead agency is to be designated, consideration of the limits of its authority is important. For example, a lead agency may be charged solely with ensuring, to the extent possible, that all Federal R&D efforts complement those of the private sector, and that there is effective transfer of results of the Federally sponsored programs. This approach may be especially useful for pursuing large scale applications which are further away in time and may not command the same level of private sector support as the electronic applications. If this path is followed, it would be important for the lead agency to be experienced in a wide range of potential application areas. Another consideration is how best to make use of existing Federal facilities. Designating an existing national lab to carry out most or all of the Federal, civilian R&D efforts in basic research and technology development, and to be responsible for cooperative research projects among industry, universities and government researchers may be one way to deal with this issue. This approach may be particularly productive in assuring that research on materials development and processing is managed effectively, and that development and testing of large scale applications, which requires extensive resources and facilities, is carried out. An alternative to a single, major R&D center might be several cooperative materials and applications development projects carried out or managed by different Federal facilities. This alternative could involve existing Materials Research Centers and Engineering Research Centers. In the case of a dispersed research effort, the question of how and to what level R&D activities among the various Federal sponsors should be coordinated still would need addressing. A final point to consider is how to interact with international activities. While an important goal of the proposals is to ensure major U.S. participation in the development and marketing of high temperature superconductors, there are and will continue to be substantial international efforts. The most efficient path to exploiting these new discoveries may be a strong international collaboration.

CONCLUSIONS

The promise of the new superconducting materials is vast, particularly if a superconductor is found that does not require external cooling and which can meet the material and engineering requirements for most applications. Despite the rapid advances seen thus far, fulfilling all of this promise will take several years. Much materials and applications development is still needed, and the large capital stock in place--e.g., generators and power cables--that could clearly benefit from the new superconducting materials will take considerable time to be replaced. The difficult problems that remain to be solved and the long-term economic potential of high temperature superconductors, however, lend urgency to beginning efforts that will best allow this nation to benefit from these exciting and promising discoveries.

Senator **Ford**. Thank you very much, Doctor. You were most kind in your summation for the Committee.

What are some of the potential applications of the new superconductors, say, for computers, electrical power, for transportation?

Dr. **Rowberg**. In the electrical power area work has been going on for some time in developing electric power generators, in developing electric power transmission systems, in electric energy storage using large electromagnets. There have been developments of electromagnets that have been used for research purposes in science as well as for the magnets used in magnetic resonance imaging devices for medical diagnostics.

In the electronics area you have very sensitive test instruments which have been used for scientific testing as well as for medical diagnostics tests in laboratories. In addition, there has been some work going on in trying to develop very high speed computers.

Senator **Ford**. Doctor, let me see if—now, I may be way off base. One of the biggest problems as it relates to solar energy is the ability to store that energy. We know how to collect it, we know how to transmit it. But we have, I think, very little way to store it.

Would this give us an opportunity to store solar energy?

Dr. **Rowberg**. Well, it would have to be indirect storage because you would have to produce the electricity first. Storing the electricity in a very large superconducting magnet could be a very promising way of storing that electric energy that could be created by solar energy, and in that sense it could provide that kind of opportunity.

Senator **Ford**. Is there any loss of energy while it is being stored? Is it diluted in any way?

Dr. **Rowberg**. The electric energy that would be stored in a superconducting system, there are basically no resistive losses in the system. In other words, the normal losses that occur in normal conductors overcoming the resistance, small as it may be, do provide certain losses in most electric power systems. There are energy losses associated with the overall system. In current technology, for example, there are energy losses associated with the refrigeration needed for liquid helium. Going to a liquid nitrogen system would reduce those losses somewhat, and clearly if we could develop a superconductor that was operating without cooling, you would reduce those even further.

Senator **Ford**. Doctor, do we need to develop new ways to commercialize this technology, or will traditional techniques be adequate?

Dr. **Rowberg**. Well, it is possible that we will need to because you have this wide range of applications involved here, all ranging from small scale electronic components to the large electric power systems. Now, clearly present industry is quite interested in the developments, and the electronics industry has undertaken a major effort, whether IBM, AT&T, duPont, et cetera, in developing these materials, and it is possible that given their interest, that additional activity beyond the Federal role of research may not be necessary.

But in the large scale applications, the diversity of end users and the resources that generally, and the fact that the electric power industry generally has not done a lot of advanced research in these areas, may mean that a more concerted effort would be helpful in producing and developing the technologies.

We have, as I said, been undergoing work in this area for some time, but most of it has been funded by Federal efforts in the sense of the power transmission lines at Brookhaven and some of the superconducting generator work at MIT, as well as the Navy applications at the David Taylor Center and so forth.

So I think that it is worth exploring a more concerted effort on the part of the Federal Government in terms of developing the technology base as needed to get these into a commercial role at some point.

Senator FORD. Thank you very much, Doctor.

Senator Domenici, do you want to go ahead with your opening statement, if you have one, and some questions for the doctor? The Congressman will be next.

STATEMENT OF HON. PETE V. DOMENICI, A U.S. SENATOR FROM THE STATE OF NEW MEXICO

Senator DOMENICI. Mr. Chairman, first let me apologize for being late, and indicate to you my real appreciation to you for calling not only this hearing but the one you have called for Thursday with reference to another technology. If I have to leave, it is because the Gramm-Rudman-Hollings conference is meeting over in the House. I do not think we are accomplishing anything there.

Senator FORD. Well, you just stay here, and I will leave at 4 o'clock, how is that?

Senator DOMENICI. I have a very lengthy explanation of where we are and where I thought we would go if we adopted some new provisions as contained in my bill. I ask that you make that statement a part of the record.

Senator FORD. Without objection, so ordered.

[The prepared statement of Senator Domenici follows:]

HEARING STATEMENT

SENATOR PETE V.DOMENICI

SEPTEMBER 15, 1987

SUBCOMMITTEE ON RESEARCH AND DEVELOPMENT

SENATE ENERGY COMMITTEE

Mr. Chairman, the origin for today's hearing can be traced back to a very historic event of February, 1987. Scientists at the University of Houston made a breakthrough in developing superconducting ceramics above the temperature of liquid nitrogen.

Four days after the announcement of this breakthrough, Japan's Science and Technology Agency announced its intent to form a research consortium of Japanese companies, universities, and governmental laboratories to implement superconductivity. A week later, the consortium was a reality, including all the major industrial concerns, as well as the leading-edge superconductivity researchers.

Today, seven months after this historical breakthrough by U.S. researchers, we are discussing --merely discussing-- whether it is appropriate to pass legislation to set up cooperative ventures at our National Laboratories.

These two timeframes, perhaps more than anything else, should jar us into the realization that we will lose a major technological race if we do not take bold, innovative steps quickly.

I introduced S. 1480, the DOE National Laboratory Cooperative Research Initiative Act, on July 10th to speed our development of superconductivity and two other technologies with significant economic potential. What this bill proposes is a reorientation of the nation's research and development system by creating new linkages between the National laboratories and private industry.

It emphasizes the need to involve industry in the early stages of research in order to ensure that research is focused on development of technologies that are desired in the marketplace. It calls for new cooperative partnerships with industry, university, and government participation. It redirects the management of technology from Washington to the National Labs, since the people best able to manage technology are those intimately involved in the scientific research.

What the DOE National Laboratory Cooperative Research Act proposes is not a clone of the Japanese approach, for our process of research and product development is considerably different than that of the Japanese and rightfully so. We have an intellectual environment in the United States that fosters independent entrepreneurial competition.

Our different approach, however, should not shield us from our past failure to capitalize on products such as VCRs, machine tools, transistors, color TVs, and broadcast equipment. For it is this ability to develop and market products which will make us technologically competitive in the future.

"Those who fail to remember the past are destined to live it again." Famous words frequently heard, with direct relevance to our future potential for superconductivity based products.

We can yell about unfair competitive practices, justified or not, and suffer the inevitable consequences, or we can change our strategy for conducting research and facilitiating the transfer of applicable technology into the marketplace.

This is what the Department of Energy National Laboratory Cooperative Research Initiative Act is all about. Recognizing our shortcomings of the past and our current strengths, we are in a good position to build new cooperative organizations to reap the financial rewards of our scientific accomplishments.

Our shortcomings have been evident. Technical and scientific cooperation has been sporadic, technology transfer has been characterized by red tape and inordinate time delays. University, industry, and government groups have too frequently worked as adversaries rather than as a U.S. team in an international race. We can ill afford to allow competition among ourselves to jeoporadize our ability to compete internationally.

Our strengths are not always as obvious as our shortcomings since we lose sight of them when we are unsuccessful. I know we have great strengths that thus far have gone untested to optimum levels. The U.S. has the greatest scientific resources of the world when it comes to basic research and development. We have the Nobel prizes to prove it. We have the brain power, the spirit and perseverence, and the management capability to do anything we set our minds to. The space race to the moon proved that with proper national focus and financial support, the United States can successfully program scientific breakthroughs.

The President's Superconductivity Initiative provided the national focus for superconductivity and definitely provided the first, essential step. He is establishing three superconductivity clearing houses for information exchange at Argonne, Lawrence Berkeley, and Ames Laboratories. On the heels of this announcement, Secretary Herrington announced that he was implementing the initiative and adding a Center at Los Alamos National Laboratory that will focus on developing relationships between the Labs and industry. The blueprint for this last Center, I am proud to say, will follow many of the specifications outlined in my bill S. 1480.

Congress now has the responsibility for the next phase of the program, to provide the framework for the funding support and the management structure for the superconductivity challenge.

Today we are trying to fine tune this structure to ensure the most effective and expeditious organization to develop products from superconductivity breakthroughs. Technological breakthroughs which we are already realizing in an exponential explosion.

The choice is simple, we can relive the past or we can forge a new future. A future that will give the U.S. the technological base it needs for a vibrant economy.

I believe that we can make progress, significant progress, if we focus on the development of technologies with the highest potential for economic payoff. The most effective means of focusing on these technologies is to pool all the relevant basic scientific expertise with the appropriate applications and manufacturing expertise. This would expedite the transition between the research and development phase and the marketing of new, innovative products.

The United States has a unique advantage over other countries in meeting this objective, if we recognize and use it. The "trade secret" I am referring to is the Department of

Energy's National Laboratories which represent a concentrated pool of talent, facilities, and scientific expertise. There are several DOE Labs which are intimately involved in studying physical, chemical and structural properties of materials as well as thin film and bulk ceramic synthesis and processing, all of which are crucial to superconductivity research.

These national resources should be the center of our focus on key technologies.

The legislation under discussion today is not a guarantee to make the U.S. competitive. We all realize there are no guarantees to such a complex issue. But, I believe it is the most comprehensive measure to date and that it will get us on the right track toward the realization of more marketable, innovative products. It takes advantage of our greatest, National scientific resource, the U.S. Labs, in a way that has never been tried before, focusing on enabling technologies. The Labs would be chosen for their demonstrated research expertise in three significant technologies: superconductivity, semiconductors, and the human Genome.

These research centers would be responsible for the development of enabling technologies, which will allow private industry to design and build marketable products. In the case of superconductivity, this could be development of superconducting wire which would be used to produce powerful magnets for a variety of applications ranging from medical diagnostic equipment to high-speed trains.

Moreover this legislation will ensure that intellectual property rights are protected, that patents can be granted expediously, and that anti-trust laws are not at odds with these new cooperative ventures.

It will also ensure that technology transfer from the National Labs into the hands of private industry is streamlined. We have consistently heard from other forums that this process is exceedingly slow and bureaucratic.

DOE has made some progress in technology transfer, as evident in the formation of 27 new companies as spin-offs of research undertaken in the National Lab system in 1986. However, the Massachuchetts Institute of Technology, with one-tenth the budget of the DOE labs, had a comparable number of spin-offs. Even given the additional national defense programs of the Labs, these statistics indicate that there is considerable room for improvement at the labs.

Mr. Chairman, since I introduced this legislation, S.1480, I have met with private industry, government and academic experts familiar with the concept of cooperative research. Consequently, I have considered all the suggestions and comments and believe that a number of modifications should be made to this legislation. As a starting point for today's hearing, I would like to list some of those changes:

1. One of the main thrusts of this bill has been to provide the National Laboratory contractor- operators with greater independence in entering into cooperative arrangements with industry and university members. However, this ability to enter into cooperative ventures and the associated funding arrangements, has created some concern that DOE could not properly carry out its oversight role. Therefore, I would add a provision to allow the Secretary of Energy to modify or cancel

a cooperative agreement within 90 days after the lab has entered into the agreement. Since one of my objectives is to treat all the Laboratories the same, this provision would be patterned after a similar provision in Stevenson-Wydler. (The Stevenson-Wydler provision under current law only applies to government-owned, government-operated Laboratories. I would expand it to apply to all Labs).

2. It has never been the intent of the bill to detract from the other essential missions of our National Laboratory system. When concern was voiced that the cooperative agreements could, conceivably, tie up too much of a lab's resources and impact on their other missions, a dollar limit was set on the aggregate of cooperative agreements entered into by any one lab. This limit can not exceed 5 % of that lab's total annual budget.

3. One of the objectives of the bill is to manage technology developed at the Laboratories differently--to have industry involved early in the process and on an ongoing basis and to speed up the transfer of technology from the labs into the private sector. Since the contractor-operator of the lab could negotiate with industrial partners in a cooperative agreement for royalty benefits, there was a concern over how the royalties earned would be used. Safeguards have been incorporated into the bill to ensure that royalties realized from cooperative arrangements would be funneled back into the laboratory's research efforts on the key technologies.

4. The intent of the bill is to develop technology management procedures which are uniform among all the laboratories, regardless of their missions. In order to accomplish this, I would expand Bayh-Dole(P.L. 96-517) to apply to all Labs and incorporate the DOD model for tech tranfer. The requirements are simple. If DOE does not classify the technology within 30 days, it is deemed transfered to the contractor-operator. This is consistent with a recent National Security Council recommendation.

To make sure that a contractor-operator does not just keep the technology sitting on a shelf, there would be a further requirement that it license it to industry giving U.S. industry something similar to a right of first refusal. Safeguards would be included to make sure small businesses as well as large businesses would be able to participate.

5. If the contractor-operator fails to license the technology, the federal government can "march in" and take it back. These provisions are similar to Stevenson-Wydler provisions, which under current law only apply to GOGOS. The bill would expand them to apply to all DOE laboratories.

6. Another objective of the bill is to encourage broad base participation in the cooperative ventures across the university and industrial sector, regardless of the size of the organization. A directive has been added to the bill to ensure that the labs meet this goal.

7. There is still an open question which I hope to hear testimony on today. Whether the technology provisions of S.1480

should apply to just the three technologies specified (superconductivity, semiconductors, and the human genome) or whether they should be applied to all technology created at the Department of Energy's National Laboratories.

Mr. Chairman, I believe that given these changes as well as future modifications based on testimony such as we have today, that this legislation will represent a major step forward. It will refocus our research efforts to recognize commercialization potential. We can no longer turn back when we are just within sight of our goal, as we are now with superconductivity. If we hope to be competitive internationally we must be more agressive in translating our scientific achievements into innovative products. Our economic viability and technological future are at stake.

Now I know that we are all anxious to hear from our witnesses today how the proposed legislation can help us accomplish our objectives for a technological secure America. I appreciate the time and effort that each witness has taken in preparing for this hearing today. We are indeed fortunate to have such a variety of perspectives and depth of scientific expertise.

Senator DOMENICI. First of all, I think we all remember the historic day that there was an announcement of the breakthrough on superconducting materials in Texas. I think it took the Japanese 11 days, Mr. Chairman, to make a major announcement, if we got our numbers right, with reference to their formation of a new major, goal-oriented consortium of business and scientists and academia in their country.

I think the facts are right. Having found that we went to work with a lot of people and hoped that the trade bill would be a vehicle for considering this, the bill that is before us was introduced. Thanks only to your genuine interest, only two months have passed since the bill was introduced and today we are having a hearing.

I know of no significant changes legislatively or policywise, except some announcements by the President at a national meeting to attempt to use a couple of National Laboratories in a little more goal oriented way.

So frankly, I am hopeful that before the year finishes we will find a way to capitalize on the knowledge and create some new linkages with our National Laboratories and private industry. I think the early involvement of industry in research and new cooperative partnerships or arrangements are absolutely necessary if we are going to succeed here. And I believe we have to redirect some of the management of these programs from Washington, D.C.'s DOE office with some strings, but nonetheless redirect it down to those National Laboratories. We must let the labs have the responsibility to form some arrangements that are new and different.

I am firmly convinced that in the past we have failed to capitalize on scientific accomplishments because it is very difficult for us to use our National Laboratories to their fullest. Technology transfer from the labs has been laden with red tape and myths. Trying to put new cooperative arrangements together with universities and the private sector is almost impossible today, and there is no way to get where we have to go unless we really do that, in my opinion.

Repeating myself for a moment, the President called a national conference and he indicated that three National Labs were going to do a little bit extra in superconducting, and then he said Los Alamos should take a lead in trying to put some partnerships together. But frankly, I do not see any of that as being sufficient or unique enough to cause the new arrangements that are necessary.

Mr. Chairman and members of the committee, I hope you appreciate the fact that in the two months since the bill was introduced, we have learned and we are fully cognizant that some of the provisions ought to be changed. If we had proceeded to get this bill adopted on the trade bill, we would have modified it on the floor, Mr. Chairman.

But first of all, there are four or five changes that I would like to describe so that the witnesses and committee members will know what has already been negotiated and worked out with various people. Hopefully the committee will end up agreeing with these changes.

One was in order not to interfere with the Laboratories' principal missions, we said we are willing to set a 5 percent limit overall on the aggregate cooperative agreements. We are willing to have some safeguards incorporated into the bill to ensure that royalties realized from cooperative agreements are funneled back into the Laboratory and key technologies. With respect to the development of a uniform technology management procedure for all the labs, we think that the use of the DOD model is better than the one we are using now. DOD has a given time to classify a technology, or if they do not, the technology is available to the contractor.

We also think that the contractor operation of the Labs should be more independent, and that they should have some independence to enter into these new arrangements. However, but we understand that DOE very much wants to keep strings, Mr. Chairman, and we are willing to propose that the labs be given freedom down at the grass roots level to enter into cooperative agreements but that the department can review these agreements. If DOE does not like them, they could cancel them after a period of time with justification.

We hope that we can modify it so that we would have some directives to assure the broadest participation in these cooperative arrangements, particularly by smaller organizations.

I would tell you that an open question of a serious nature remains in my mind. It is up to you and the committee to determine whether technology transfer provisions in this bill, that we will work on as a result of these hearings, should just apply to these three technologies or should it apply across the board in the laboratory. Should it be specific to these new initiatives, or should it be generic in nature?

And frankly, I would obviously settle for the specific one, but the more I get into it, the more I am convinced that if we are going to get the technology out, it might have to be generic.

So I want to say that with your help and this committee's, I believe that we can take a major step. We can refocus some of this research and realize commercialization potential much quicker. I am firmly convinced that we need to do this to remain competitive. It is, in my humble opinion, a deplorable state of affairs that we have not found a way to better use these magnificent National Laboratories in conjunction with academia and the private sector. I think these labs are a treasure and they are being wasted if we do not find some better ways of using them.

Thank you very much.

Senator FORD. Senator Bingaman?

STATEMENT OF HON. JEFF BINGAMAN, A U.S. SENATOR FROM THE STATE OF NEW MEXICO

Senator BINGAMAN. Mr. Chairman, let me just also compliment you on having this early hearing on Senator Domenici's legislation, S. 1480, which of course deals with the involvement of the National Labs and the Department of Energy in this key technology.

I guess my main interest in the hearings, of course, results from the presence of the laboratories in our state and my concern about them, but also as Chair of the Defense Industry and Technology Subcommittee of Armed Services, we have taken some actions that relate to superconductivity in that Defense authorization bill that is on the floor. I think that it is crucial that we have a good cooperative relationship going between the various Federal agencies that are involved in this particular Department of Defense and the Department of Energy.

I am particularly interested in questioning, as we get into the questioning, about the way that that cooperative relationship will work. I know DARPA has some additional money which we have put into the Defense authorization bill, or will have in this next fiscal year, which it can use in this particular area, and I want to assure you that there is a close integration between DOD and DOE programs.

I would, of course, just conclude by underscoring much of what Senator Domenici said about the importance of having the National Labs play a key role in this. I think they do have immense resources and talent that we need to ensure is put to the best use for the country, both in the defense and commercial sectors.

Senator **Ford**. Senator Hecht?

Senator **Hecht**. Thank you. No questions.

Senator **Ford**. Any other questions of Dr. Rowberg?

Doctor, thank you, and we appreciate your coming today and look forward to working with you in a closer manner.

Congressman, is the Congressman here yet?

Well, maybe he will just submit his statement for the record. I have been working on pronunciation of his name.

Let's start with the first panel, Dr. Decker, Dr. Graham, Dr. Nicholson and Dr. Kerber, if you will come forward, and we will start in this order: Dr. Decker, Dr. Graham, and then Dr. Nicholson, as I call them to the panel, and then Dr. Kerber.

If you would like to start, Dr. Decker, we would be more than happy.

STATEMENT OF DR. JAMES F. DECKER, ACTING DIRECTOR, OFFICE OF ENERGY RESEARCH, DEPARTMENT OF ENERGY

Dr. **Decker**. I am pleased to have the opportunity to appear to discuss S. 1480. Today I will limit my remarks to the technology transfer and superconductivity initiative portions of this bill.

The Department supports the goal of this bill to improve cooperation between the Department's National Laboratories, industry, and universities. We are in a very competitive environment in science and technology. In many areas of technology in which this country used to dominate, we are being strongly challenged from abroad and may soon be playing catch-up. Improved cooperation between the Department's laboratories and industry as well as universities will help maximize our resources to improve our competitive position.

One aspect of S. 1480 to be covered in this hearing is technology transfer. I would like to update the committee on some recent steps that the Department and its laboratories have recently taken to improve technology transfer.

First, I would like to address patents. Significant progress has been made in modifying contracts for the operation of the Department's laboratories to include patent rights, giving the contractor title to inventions under Public Law 98-620. Also, as soon as the necessary regulatory review is obtained, the Department will be issuing class patent waivers which will provide an opportunity for all contractors, including for-profit laboratory contractors, to automatically obtain title to inventions.

In addition to changes in patent policy, some new approaches to technology transfer are being tried. So-called adjunct organizations are being established at laboratories to license technology to interested users. One example, at the Argonne National Laboratory, called Argonne-University of Chicago Development Corporation, is the first U.S. development corporation involving a university and a National Laboratory to foster commercialization of technologies developed by both institutions.

I would also like to mention that a consortium with industry is being formed at the Oak Ridge National Laboratory in the area of ceramics.

Turning quickly to the topic of superconductivity, the Department has had a longstanding interest in superconductivity and a history of working with industry on the development and construction of superconducting devices. It has funded basic research in superconductivity in its usual role of supporting basic research related to energy applications. In addition, the Department has also supported development of superconducting materials for specific applications within its own research programs, namely, for magnets for accelerators and magnetic fusion.

When recent discoveries of new, high temperature superconducting compounds became known, the Department recognized the potential impact on energy systems and moved aggressively, taking a number of steps to accelerate research, to improve the flow of information and to lay the foundation for transferring the technology to industry.

We quickly redirected funding to mount a significant research effort. We have also taken the lead in a cooperative interagency effort to improve the exchange of scientific information in this field. As part of the President's Superconductivity Initiative, the Ames Laboratory has been designated the center for information on the properties of high temperature superconductors.

Also as part of the President's Initiative, the Department has announced the formation of two R&D centers. The Argonne National Laboratory will be the focal point for research and information on conductor applications. Argonne is part of the laboratory consortium that includes Ames and Brookhaven. Berkeley will serve as a focal point for applications in electronic devices, and is part of a consortium that includes Oak Ridge and Los Alamos.

And then recently, the Secretary directed Los Alamos to examine mechanisms for cooperative ventures between DOE laboratories, U.S. industries and universities.

Now I would like to turn to some specific comments on S. 1480. One of the main thrusts of S. 1480 is formation of laboratory-industry consortia. As I have indicated in my discussion of technology transfer and our support of superconductivity, our laboratories are actively working to help form and work with industry consortia. I mentioned two examples today, Los Alamos in superconductivity and Oak Ridge in ceramics.

In my testimony on Thursday before this committee I will mention a third example in the human genome area. Our laboratories are able to implement such initiatives under existing laws, regulations, and missions of the Department. In fact, this action is encouraged by the President's Executive Order No. 12591 of April 10, Facilitating Access to Science and Technology.

The overall thrust of that Executive Order is to ensure that all Federal agencies and laboratories assist universities and the private sector in broadening the technology base by moving new technologies from research laboratories into the development of new products and processes. It has provisions for establishing consortia among laboratories, universities and industries and provides the Department with necessary flexibility to implement our mutual objectives effectively.

This is a relatively new approach for the Department, and we expect to learn from each of our attempts, fix the problems and try to replicate the successes.

I have some specific concerns about S. 1480, although Senator Domenici indicated that revisions to the bill are being made which may address some of our concerns. In contrast to our present approach on these consortia, the legislation would preclude any effective program management role that would allow the Department to be able to carry out its responsibilities. For example, section 203 would permit the laboratory contractors to make funding decisions unilaterally that would require the Department to pay the cost of specific R&D activities over which it has no management or decision authority. In effect, no DOE program approval process is included for cooperative R&D agreements that could result in future year budget mortgages for the Department.

Some of the provisions are inconsistent not only with our current policy but also with existing Federal laws and DOE statutes regarding intellectual property rights, copyrights, trade secrets and so forth.

Section 306, for example, would give rights to the laboratories for trade secrets and proprietary data arising out of their R&D. I think this would compromise the current atmosphere of open publication of research data and inhibit the effective operation of the integrated contractor system that has been a strength of the DOE labs.

In repealing the Defense Program and Naval Propulsion exemption, Bayh-Dole, section 306 of the legislation would also give eligible contractors the right to elect title to inventions arising under DOE weapons-related and nuclear propulsion programs. This would negatively impact the integrated contractor system that is key to the effective management of the weapons program.

Attempts to make major revisions in data rights and trade secrets policy issues require careful review, I think, by all of the agencies. As proposed in 1480, that legislation would create contractor property rights in data for the first time, and as I said, could impede the flow of research information among laboratories, to the scientific community and to the public. Transferring intellectual property rights in the nuclear weapons program and naval reactors programs from the government to the contractors as in sections 102, 203 and 306 could result in promoting an atmosphere of private gain through the commercialization of motivation.

The Office of Management and Budget's Office of Federal Procurement Policy is developing a government policy regarding ownership of technical data produced under Federal contracts. Legislation which provides standards and applies to a single initiative of a single agency would, under the circumstances, be premature.

In conclusion, while the Department of Energy shares the overall goals of S. 1480, the proposed bill in our view has several flaws that would not permit the Department to carry out effective management of its programs and current legal obligations.

[The prepared statement of Dr. Decker follows:]

Statement of James F. Decker

Acting Director of the Office of Energy Research

U.S. Department of Energy

before the

Subcommittee on Energy Research and Development

of the

Senate Energy and Natural Resources Committee

September 15, 1987

Mr. Chairman and Members of the Subcommittee:

It is a pleasure to be with you to discuss the technology transfer efforts of the Department of Energy (DOE) in two important areas of technology, superconductivity and semiconductors, both highlighted in S. 1480. I will also comment on selected aspects of the bill that cause the Department some real concern. In particular, we believe that the authority that the bill provides to DOE laboratory contractors to make unilateral funding decisions would have a serious negative impact on the Department's ability to manage its programs effectively. I will discuss this particular problem in more detail later in my statement. We have a number of other concerns which we currently are discussing with Subcommittee staff.

Let me make clear at the outset that the Department fully supports the goal of S. 1480 which is to improve cooperation among universities, industry and the national laboratory system of the Department. Through cooperative research, our mutual goal is to accelerate the commercialization of technology developments in areas that offer significant economic potential. The goal of the bill is certainly in line with the long-term track record of the Department and its laboratories in working with universities and industry to enhance the science and technology base that supports industrial development. Historically, DOE laboratories have developed the technological base for entire new industries such as nuclear power and nuclear medicine, as well as major advances in supercomputers and precision machining and engineering.

Specific technologies that have been transferred from DOE laboratories to the marketplace are as diverse as a cell separator that aids in cancer treatment, a diamond-tipped drill bit for oil exploration, and a solar heat collector system to provide inexpensive hot water to industry. Although very different, each of these technologies resulted from Federally sponsored research in DOE laboratories, and each crossed the traditional boundaries separating government, industry and the academic community as it moved into the commercial marketplace.

The Department's impressive record in technology transfer continues to grow. Let me cite just a few statistical examples. Last year, scientists and engineers at DOE laboratories received 21, or one-fifth, of the IR-100 Awards presented by Research and Development Magazine annually for the most significant technology products, processes, and materials with market potential. In 1987 we understand that DOE laboratories will receive an even larger share of these awards. Since 1981, the number of industrial users participating in experiments at the major DOE user facilities has doubled. In 1986 some 500 companies took advantage of the resources at the user facilities. We also have made impressive progress in pursuing collaborative research projects with industry. Since 1981, the number of collaborative projects has doubled and their dollar value has increased six-fold to more than $16 million annually. The number of new companies that were formed based on DOE laboratory technology has increased five-fold since 1981, with 77 companies formed in 1985-86.

In a specific recent example of one method used to transfer technology, the Department has waived its patent rights to a DOE process developed to remove nitrogen oxides from the exhaust gases of engines and furnaces. This process, which may have commercial applications for cleaning combustion exhausts, is called RAPRENO$_x$. It was invented at Sandia National Laboratories-Livermore and has received a 1987 IR-100 award. The inventor has since left the laboratory, formed his own company and intends to market his innovation.

The Department has consistently supported technology transfer initiatives and efforts aimed at reducing institutional barriers to the transfer of technology from its laboratories. Numerous improvements have been made in recent years including providing more flexibility for laboratory staff to consult for industry and developing class waivers for patents originating from user facilities and work for others agreements. We are also working on developing a system that puts universities, small businesses and for-profit contractors on the same footing.

To facilitate technology transfer, DOE laboratory contractors will have the right to retain ownership of all inventions arising from federally funded R&D, except those from defense-related and other sensitive programs. DOE is working to develop an expedited waiver system to address those defense-related exceptions on a case-by-case basis in a timely manner. For the not-for-profit or university contractors, all the authorities are now in place and negotiations are underway. Five of the laboratories already have modified contracts; three have been fully negotiated and await signature, and five others are now being negotiated. For the for-profit contractors, the

Department has developed a class patent waiver that is currently under Executive Office review and is consistent with government rulemaking procedures. In the near future, these proposed class patent waivers will be published in the Federal Register for public comment and, when issued, will result in for-profit contractors receiving rights similar to the non-profit contractors.

There are several recent examples of improvements in DOE technology transfer through the licensing of technology developments to interested users. The number of laboratory-issued licenses doubled from 1985 to 1986. Overall in 1986, Oak Ridge National Laboratory had ten technologies licensed, and Sandia National Laboratories and Los Alamos National Laboratory each had nine. Several of the laboratories are establishing adjunct organizations to license new technology to interested users. An example of such an organization is ARCH, at Argonne National Laboratory, which has just issued its first license. Already of commercial importance are the ORNL-developed, whisker-toughened ceramic composites, which have been licensed to industry for application in cutting tools and parts exposed to heavy wear. They can operate at ten times the speed and last seven times as long as conventional materials.

We expect the Department's solid record of performance in technology transfer to continue to grow, aided in part by new initiatives aimed at promoting increased cooperation among Federal agencies, universities and industry. Of note among these is the President's April 10, 1987 Executive

Order No. 12591 on Facilitating Access to Science and Technology. With current statutory authority and this Executive Order, we believe that we can achieve the goal of the currently proposed legislation, S. 1480.

COMMENTS ON S. 1480

The Department believes that the initiatives called for in this Executive Order meet the goal of S. 1480. In a moment I will discuss how the Department is implementing the Executive Order. But first I would like to express the Department's concerns about several aspects of S. 1480. As I noted earlier, the Department fully supports the goal of the bill. However, it is very important that the Department retain the ability to carry out its laboratory oversight role. It is equally important for the Department to have an effective program management role in the operation and review of its laboratories.

Laboratory contractors should not have the discretion to commit public funds unilaterally without DOE approval. Such a situation would cause many problems. For example, funds for research to be carried out in any given year are proposed, approved and are made available as a part of the annual budget process. This process cannot anticipate unilateral commitments made by laboratory contractors. The discretion assigned to laboratory contractors could also have the effect of abrogating the Federal government's responsibility to manage its programs.

The Department strongly believes that DOE should review cost-sharing agreements that could result in future year mortgages for the Department. In addition, a number of provisions in the bill require additional study. For example, the Office of Management and Budget's Office of Federal Procurement Policy, in accordance with Executive Order No. 12591, is developing a government wide policy regarding ownership of technical data produced under federal contacts. Legislation which provides no standards and applies to a single initiative of a single agency would, under these circumstances, be premature.

EXECUTIVE ORDER ON FACILITATING ACCESS TO SCIENCE AND TECHNOLOGY

As I noted earlier, the Department believes that the goal of S. 1480 is fully met by the President's Executive Order No. 12591, and that we are making substantial progress in implementing that Order.

The Executive Order directs that several steps be taken to improve the transfer of Federally developed technology and information to the marketplace by facilitating collaboration among universities, federal laboratories, and the private sector. The Departmental initiatives in science and technology to implement the Order will significantly enhance highly visible collaboration and cooperation between the national laboratories and the private sector. Let me focus first on DOE activities related to superconductivity.

Superconductivity

The Department has had a long standing interest in superconductivity because of its use in several DOE programs such as High Energy Physics, Fusion, and electric transmission, generation, and storage. Since the days of the Atomic Energy Commission, a predecessor to the Department, DOE's support of basic research related to superconductivity and the procurement of superconducting devices for its programs have had a major positive impact on the economic viability of the currently small U.S. superconductor industry. For example, the Department's Fermi National Accelerator Laboratory completed the world's largest superconducting project, the superconducting Tevatron accelerator, which contained 900 magnets using 60 tons of niobium-titanium superconductor supplied by industry. The Department's involvement in the development of high-temperature superconductors has been and will continue to be substantial, as will our contributions to the development of a U.S. superconductor industry.

Because of its research responsibilities, the Department of Energy has traditionally had the largest Federal program in superconductivity. This program has ranged from basic research on theory and structure to the actual construction and use of large superconducting magnets and electrical generation, transmission and storage devices for research and development.

With the discovery this year of superconductors that can operate at temperatures attainable with liquid nitrogen (77 Kelvin) rather than the much colder liquid helium (4 Kelvin), DOE has been at the forefront of both the research and the technology transfer activities. Significant research programs have been started on the new oxide superconducting materials at seven of the Department's laboratories. In order to better coordinate this swiftly moving field, three coordinating meetings have been held, bringing together not only the DOE laboratories, but also U.S. industry and university researchers. A fourth meeting is scheduled at Argonne National Laboratory on September 21-22, 1987. With the proliferation of researchers and results in this exciting area, the Department established a mechanism for exchanging publications and news items, the Ames Laboratory "High T_c Update." This newsletter has become the prime information exchange mechanism in high temperature superconductivity and is supported by DOE and other Federal agencies now.

Unlike the older lower temperature superconductors, the new materials are brittle, difficult to fabricate and have some technical obstacles which must be overcome before any widespread applications are possible. The DOE laboratories have made significant contributions to progress towards our ultimate goal of commercialization. These contributions have been in the areas of theory, structure determinations using the DOE major facilities, processing the ceramics into wire and ribbon form, synthesis of materials and understanding the origin of the unusual properties of these oxides.

We are also moving rapidly to couple the DOE program with U.S. industry and other researchers. The Department has established four centers to conduct research on superconductivity and to act as sources of information in response to the President's Superconductivity Initiative. These four centers are at Argonne National Laboratory, Lawrence Berkeley Laboratory, Ames

Laboratory, and the Office of Scientific and Technical Information at Oak Ridge. Argonne National Laboratory will be the focal point for information on conductor applications, for example, magnets for accelerators and medical imaging devices, conductors for electrical power transmission, storage and conversion, and conductors for magnetically levitated trains. Lawrence Berkeley Laboratory will serve as the focal point for applications in electronic devices, for example, radiation detectors, magnetic field sensors, and computer applications. Ames Laboratory will coordinate information on the fundamental and generic properties of the high temperature superconductors. In addition to these centers, which are in operation now and will provide day-to-day information to U.S. industry, a computer-based data center is being established at the DOE Office of Scientific and Technical Information, Oak Ridge. This will be a repository of reports and work in progress accessible through a computer link. The system is now being instituted on an experimental basis with DOE laboratories. Eventually it will be extended to all qualified users.

In a closely related initiative, the Secretary of Energy has asked Los Alamos National Laboratory to lead an effort to examine mechanisms for cooperative ventures among DOE laboratories, U.S. industry and universities. This study will be led by Los Alamos with the intent of extending the partnership mechanisms to other laboratories.

Semiconductors

DOE research on semiconductors is focused on meeting the special needs of the Department or on projects that involve the special expertise available only at DOE laboratories. The Department has played an important role in the development of the U.S. semiconductor technology base. We continue to support basic research in this area.

Semiconductors are materials which form the base for all solid state microelectronics circuitry. In the Department, programs under the Assistant Secretary for Defense Programs needed radiation hardened integrated circuits and have built up significant expertise for that purpose. This has required the development of fabrication techniques and facilities that are unique in the country. DOE's renewable energy program under the Assistant Secretary for Conservation and Renewable Energy also utilizes semiconductors such as silicon to convert solar radiation into electricity. This program, although not aimed at the electronics industry, has developed important techniques and expertise related to microelectronics semiconductor applications. In developing this application for solar energy conversion, called photovoltaics, the DOE solar energy program has worked extensively with U.S. industry. This has been a very successful partnership, with the technology now being made available commercially while further developments and improvements are underway. In addition, semiconductor basic research is being pursued in the Office of Energy Research's programs. This work involves research on theory, processing of elemental and compound semiconductors, characterization of semiconductor materials, preparation of research materials and novel semiconductor materials and the use of major facilities for the study of semiconductors.

Despite the limited scope of the DOE semiconductor research programs, the expertise at the DOE laboratories in this area continues to be sought after by U.S. industry. We have had several workshops together with U.S. industry to communicate the resources, in terms of expertise and research facilities, available at the laboratories and to understand industry needs. This interaction has been pursued vigorously in several areas.

Workshops have been held at Brookhaven National Laboratory to examine the possibility of using small, specially designed synchrotron light sources to produce x-rays for the lithographic step in integrated circuit fabrication. The workshops have included U.S. industry and have resulted in agreed-upon designs and approaches. Design refinement has been continued with funding from the Department of Defense. Other workshops have focused on advanced semiconductor processing and diagnostic techniques. Cooperative programs have already begun in areas of mutual interest such as plasma processing and gallium-arsenide preparation and characterization. Discussions are continuing to focus on areas of mutual need and interest, for example, fabrication and design. Our communication links with industry are excellent. We have set up a semiconductor task force with representatives from nine DOE laboratories. Where areas of mutual interest are identified, there appears to be no obstacle to establishing cooperative programs with industry. In areas that require significant additional funds, such as the compact x-ray synchrotron, the

Department cannot divert existing funds but is willing to make available DOE expertise. Other areas need to be examined carefully to determine that expertise and resources are not diverted from the main mission of the Department.

CONCLUSION

In announcing the Executive Order No. 12591 on Science and Technology, the President stated that, "a vigorous science and technology enterprise involving the private sector is essential to our economic and national security as we approach the 21st century...It is important not only to assure that we maintain American preeminence in generating new knowledge and know-how in advanced technologies, but also that we encourage the swiftest possible transfer of federally developed science and technology to the private sector. All of the provisions of this Executive order are designed to keep the United States on the leading edge of international competition." I believe that the Department currently has the Executive Office support and legislative authority that it needs to move toward the goals expressed by the President and found in S. 1480.

This concludes my statement. I would be pleased to respond to questions.

Senator FORD. Thank you very much.
Dr. Graham?

STATEMENT OF DR. WILLIAM R. GRAHAM, SCIENCE ADVISER TO THE PRESIDENT, AND DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY, THE WHITE HOUSE

Dr. GRAHAM. Thank you, Chairman Ford, members of the committee. It is a pleasure to appear before you today to discuss the proposed legislation, S. 1480, the DOE National Laboratory Cooperative Research Initiatives Act.

Both the Congress and the administration continue to demonstrate their commitment to use our strength in science and technology to promote the competitive position of the United States in a global economic environment. This legislation is evidence that your goal is to improve the Department of Energy National Laboratories links to the universities and industry of this country in order to streamline the transfer of technology to the marketplace. It is obvious that the administration and the Congress share a vision of using American ingenuity to drive a powerful and vibrant economy as well as to protect our national security.

Before I address the titles on technical transfer and on superconductivity today, I would like to make a few observations about the legislation and how it fits with other initiatives under development within the Federal Government.

First, science and technology centers. As you know, the President has sent Congress a request to establish within the National Science Foundation science and technology centers designed to form a cooperative association between American universities, industry, and government laboratories. We believe that these centers can be catalysts for appropriate exchange that will allow the scientists and engineers working in basic research to conduct a two-way transfer of ideas and challenges with entrepreneurs and developers in the corporations of America. In return, technologists working in the corporate research laboratories can assist their university colleagues by instilling a sense of real-world problems and priorities and the urgency that industry has into the government's basic research agenda.

In testimony earlier this year I expressed my intent to work to see this concept expanded in future years to agencies in addition to the National Science Foundation, and to the nation's Federal laboratories. I believe that S. 1480 indicates that Senator Domenici and we in the administration share many of the same goals. You may be sure that the concepts of cooperative research centers for the purpose of rapid identification of challenges and transfer of technology will be supported by the Reagan Administration.

Concerning specifically technology transfer, the administration has also supported initiatives of Congress to improve the technology transfer between our universities, industries and government laboratories. In particular, we have approved authority for the operators of the government-owned, government-operated laboratories to enter into cooperative R&D agreements, and in that context, make suitable agreements relating to the disposition of intellectual property rights.

But much more generally, under Executive Order 12591, the President has directed the heads of all executive agencies to assure efficient use of all Federal laboratories and to transfer commercially useful technologies to industry as expeditiously as possible.

As Dr. Decker mentioned, as an example of this, under the executive order and related policies, the Argonne Laboratory has established ARCH, the Argonne National Laboratory-University of Chicago Development Corporation, which is focused on facilitating that technical transfer and supporting it in a broad range of areas, not only including the technology itself, but also in financial, business and managerial planning of making that technology a commercial success.

Concerning high temperature superconductors, the Title I provision to establish cooperative research centers in enabling technology for superconducting materials and applications at National Laboratories with appropriate university and private industry participants is certainly in consonance with the objectives of the President's executive order on facilitating access to science and technology, and the President directed the establishment of such centers as one of the 11 items in his superconductivity initiative announcement on July 28 this year.

I believe such centers will be formed at four different Federal laboratories in total, and in addition, an information resources center will be established at Oak Ridge under the Department of Energy auspices. The formation of a council for research on enabling technologies, comprising representatives from government, universities and industry, after consultation with Senator Domenici, was also addressed in the President's superconductivity initiative, and a directive to establish a wise men advisory group under the auspices of the White House Science Council, has been issued by the President in order to create an advisory mechanism for the administration on high temperature superconductivity research and commercialization policies.

And as the White House Science Council reports to me and through me to the President and other agencies of the government, I can assure you we are taking that most seriously and moving aggressively in that area.

I would also like to note that the recently formed Independent Council on Superconductivity for American Competitiveness will be chaired by my colleague and former Science Advisor Dr. George Keyworth, a private sector initiative.

Mr. Chairman, the administration has listened carefully to Senator Domenici and this Senate and has already acted in many of the areas that he has suggested. In terms of the technology transfer, we believe that the mechanisms in place under the Technology Transfer Act of 1986 and under Executive Order 12591 in fact establish a strong policy framework and set of specific directions to the agencies to facilitate the transfer of technology and to support and encourage and strengthen the cooperation between Federal laboratories, the private sector and the universities.

Therefore, in both of these areas we believe that the proposed legislation will duplicate authority given by the President to the Department of Energy and other agencies and is not required at this time because we had already moved out and acted.

Thank you very much.

[The prepared statement of Dr. Graham follows:]

REVISED

PROPOSED TESTIMONY
OF
WILLIAM R. GRAHAM
SCIENCE ADVISER TO THE PRESIDENT
AND
DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY

BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

2:00 P.M., SEPTEMBER 15, 1987
ROOM SD-366, DIRKSEN SENATE OFFICE BUILDING
WASHINGTON, D.C.

S.1480
DEPARTMENT OF ENERGY NATIONAL LABORATORY
COOPERATIVE RESEARCH INITIATIVE ACT

CHAIRMAN FORD AND MEMBERS OF THE COMMITTEE, IT IS A PLEASURE TO APPEAR BEFORE YOU TODAY TO DISCUSS PROPOSED LEGISLATION S.1480, THE DOE NATIONAL LABORATORY COOPERATIVE RESEARCH INITIATIVES ACT.

I AM ENCOURAGED THAT THE CONGRESS IS CONTINUING TO DEMONSTRATE ITS COMMITMENT TO USE OUR STRENGTH IN SCIENCE AND TECHNOLOGY TO PROMOTE THE COMPETITIVE POSITION OF THE UNITED STATES IN A GLOBAL ECONOMIC ENVIRONMENT. THIS LEGISLATION IS EVIDENCE THAT YOUR GOAL IS TO IMPROVE THE DEPARTMENT OF ENERGY NATIONAL LABORATORIES' LINKS TO U.S. UNIVERSITIES AND INDUSTRY IN ORDER TO STREAMLINE THE TRANSFER OF TECHNOLOGY TO THE MARKETPLACE. I COMMEND SENATOR DOMENICI FOR HIS CONTINUING EFFORTS TOWARD THIS END. WHILE I DO NOT ENDORSE ALL THE PROVISIONS CONTAINED IN S.1480, IT IS OBVIOUS THAT WE SHARE A VISION OF USING AMERICAN INGENUITY TO DRIVE A POWERFUL AND VIBRANT ECONOMY AS WELL AS TO PROTECT OUR NATIONAL SECURITY.

BEFORE I ADDRESS EACH TITLE OF THE BILL IN ORDER OF OCCURRENCE, I WOULD LIKE TO MAKE A FEW OBSERVATIONS ABOUT THIS LEGISLATION AND HOW IT FITS WITH OTHER INITIATIVES UNDER DEVELOPMENT WITHIN THE FEDERAL GOVERNMENT.

SCIENCE AND TECHNOLOGY CENTERS:

AS YOU KNOW, THE PRESIDENT HAS SENT CONGRESS A REQUEST TO ESTABLISH WITHIN THE NATIONAL SCIENCE FOUNDATION SCIENCE AND TECHNOLOGY CENTERS DESIGNED TO FORM A COOPERATIVE ASSOCIATION BETWEEN AMERICAN UNIVERSITIES, INDUSTRY, AND GOVERNMENT LABORATORIES. WE BELIEVE THAT THESE CENTERS CAN BE CATALYSTS FOR APPROPRIATE EXCHANGE THAT WILL ALLOW THE SCIENTISTS AND ENGINEERS WORKING IN BASIC RESEARCH TO CONDUCT A TWO-WAY TRANSFER OF IDEAS AND CHALLENGES WITH ENTREPRENEURS AND DEVELOPERS IN THE CORPORATIONS OF AMERICA. IN RETURN, THE TECHNOLOGISTS WORKING IN THE CORPORATE RESEARCH LABORATORIES CAN ASSIST THEIR UNIVERSITY COLLEAGUES BY INSTILLING A SENSE OF REAL-WORLD PROBLEMS AND THEIR URGENCY TO THE GOVERNMENT'S BASIC RESEARCH AGENDA.

IN TESTIMONY EARLIER THIS YEAR BEFORE THE HOUSE SPACE, SCIENCE, AND TECHNOLOGY COMMITTEE, I EXPRESSED MY INTENT TO WORK TO SEE THIS CONCEPT EXPANDED IN FUTURE YEARS TO AGENCIES IN ADDITION TO THE NATIONAL SCIENCE FOUNDATION AND TO THE NATION'S FEDERAL LABORATORIES. I BELIEVE THAT S.1480 INDICATES THAT SENATOR DOMENICI AND WE IN THE ADMINISTRATION SHARE MANY OF THE SAME GOALS. YOU MAY BE SURE THAT THE GENERAL CONCEPT OF COOPERATIVE RESEARCH CENTERS FOR THE PURPOSE OF RAPID IDENTIFICATION OF CHALLENGES AND TRANSFER OF TECHNOLOGY WILL BE SUPPORTED BY THE REAGAN ADMINISTRATION.

TECHNOLOGY TRANSFER:

AS YOU KNOW, THE ADMINISTRATION HAS ALSO SUPPORTED INITIATIVES OF CONGRESS TO IMPROVE TECHNOLOGY TRANSFER BETWEEN OUR UNIVERSITIES, INDUSTRIES AND GOVERNMENT LABORATORIES. IN PARTICULAR WE HAVE APPROVED AUTHORITY FOR THE OPERATORS OF THE GOVERNMENT-OWNED, GOVERNMENT-OPERATED (GOGO) LABORATORIES TO ENTER INTO COOPERATIVE R&D AGREEMENTS AND, IN THAT CONTEXT, MAKE SUITABLE AGREEMENTS RELATING TO THE DISPOSITION OF INTELLECTUAL PROPERTY RIGHTS.

UNDER EXECUTIVE ORDER 12591 THE PRESIDENT HAS DIRECTED THE HEADS OF ALL EXECUTIVE AGENCIES TO ASSURE EFFICIENT USE OF ALL FEDERAL LABORATORIES AND TECHNOLOGIES TO INDUSTRY AS EXPEDITIOUSLY AS POSSIBLE.

AS AN EXAMPLE, UNDER THIS AND RELATED POLICIES, THE ARGONNE LABORATORY HAS ESTABLISHED ARCH (ARGONNE NATIONAL LABORATORY-THE UNIVERSITY OF CHICAGO DEVELOPMENT CORPORATION) (SEE ATTACHMENT REGARDING ARCH).

FUNDING ALLOCATIONS:

AS YOU KNOW, THE PRESIDENT HAS SUBMITTED TO CONGRESS A BUDGET FOR FY 1988 INTENDED TO MEET THE GRAMM-RUDMANN-HOLLINGS TARGETS. THIS BUDGET WAS PRODUCED AFTER MUCH DEBATE WITHIN THE EXECUTIVE OFFICE AND EACH COMPONENT WAS EXAMINED IN CAREFUL DETAIL FOR ITS ABSOLUTE NECESSITY. I AM PLEASED TO STATE THAT EVEN AFTER SUCH CAREFUL SCRUTINY, THIS BUDGET CONTAINED A SUBSTANTIAL GROWTH IN THE SCIENCE AND TECHNOLOGY PROGRAMS AND EVEN MADE A COMMITMENT TO DOUBLE THE BUDGET FOR THE NATIONAL SCIENCE FOUNDATION OVER THE NEXT FIVE YEARS. IN TAKING SO BOLD A POSITION, THE PRESIDENT DEMONSTRATED HIS STRONG BELIEF IN THE POWER OF SCIENCE AND TECHNOLOGY TO SUPPORT THE ECONOMIC FUTURE OF THIS NATION.

TODAY I REAFFIRM MY SUPPORT FOR THE GOALS CONTAINED IN THE PRESIDENT'S BUDGET. I COULD NOT, HOWEVER, AGREE TO INCREASE TAXES, REDUCE SPENDING IN OTHER AREAS OF THE BUDGET, OR WITHOUT GOOD REASON TO MOVE FUNDS FROM ONE AREA OF SCIENCE AND TECHNOLOGY TO ANOTHER. I AM LIKEWISE CONCERNED ABOUT THE INCREASING TREND TO BURDEN THE DEPARTMENT OF ENERGY WITH PRESCRIPTIVE LEGISLATION WHICH PREEMPTS ITS OWN MANAGERIAL EFFORTS TO CONDUCT A BALANCED AND EFFECTIVE PROGRAM OF RESEARCH. IN PARTICULAR, THE BASIC ENERGY SCIENCES PROGRAM (WHICH INCLUDES SUBSTANTIAL FUNDS FOR THE NATIONAL LABORATORIES) CURRENTLY SUPPORTS SUCH BASIC RESEARCH THAT IS ESSENTIAL TO OUR LONG-TERM COMPETITIVENESS.

WITH YOUR PERMISSION, I WOULD NOW LIKE TO ADDRESS EACH TITLE OF S.1480 INDEPENDENTLY.

TITLE I - HIGH TEMPERATURE SUPERCONDUCTORS:

THE TITLE I PROVISION, TO "ESTABLISH COOPERATIVE RESEARCH CENTERS IN ENABLING TECHNOLOGY FOR SUPERCONDUCTING MATERIALS AND APPLICATIONS AT NATIONAL LABORATORIES WITH APPROPRIATE UNIVERSITY AND PRIVATE INDUSTRY PARTICIPANTS," IS IN CONSONANCE WITH THE OBJECTIVES OF THE PRESIDENT'S EXECUTIVE ORDER 12591, "FACILITATING ACCESS TO SCIENCE AND TECHNOLOGY" AND, THE PRESIDENT DIRECTED THE ESTABLISHMENT OF SUCH CENTERS AS ONE OF THE ELEVEN ITEMS IN HIS SUPERCONDUCTIVITY INITIATIVE ANNOUNCED ON JULY 28, THIS YEAR. THE FORMATION OF A COUNCIL FOR RESEARCH ON ENABLING TECHNOLOGIES COMPRISING REPRESENTATIVES FROM GOVERNMENT, UNIVERSITIES, AND INDUSTRY, AFTER CONSULTATION WITH SENATOR DOMENICI, WAS ALSO ADDRESSED IN THE PRESIDENT'S SUPERCONDUCTIVITY INITIATIVE, AND A DIRECTIVE TO ESTABLISH A "WISE MEN" ADVISORY GROUP UNDER THE AUSPICES OF THE WHITE HOUSE SCIENCE COUNCIL HAS BEEN ISSUED IN ORDER TO ADVISE THE ADMINISTRATION ON RESEARCH AND

COMMERCIALIZATION POLICIES. IN THIS REGARD, I WOULD ALSO LIKE TO NOTE THE RECENT FORMATION OF AN INDEPENDENT "COUNCIL ON SUPERCONDUCTIVITY FOR AMERICAN COMPETITIVENESS," CHAIRED BY MY COLLEAGUE AND FORMER SCIENCE ADVISER DR. GEORGE KEYWORTH.

THE ADMINISTRATION HAS LISTENED TO SENATOR DOMENICI, AND HAS ALREADY ACTED. THEREFORE, THE PROPOSED LEGISLATION RELATING TO SUPERCONDUCTIVITY WOULD DUPLICATE THE AUTHORITY GIVEN BY THE PRESIDENT TO THE DEPARTMENT OF ENERGY AND OTHER AGENCIES.

TITLE II - MAPPING THE HUMAN GENOME:

DEVELOPMENT OF AN ORDERED SET OF DNA FRAGMENTS TO FORM A PHYSICAL MAP AND TO SEQUENCE DNA IS UNDOUBTEDLY A WORTHWHILE SCIENTIFIC ENDEAVOR. ACCESS TO BOTH A SET OF FRAGMENTS AND A COMPUTERIZED DATABASE OF HUMAN DNA SEQUENCES WILL RELIEVE RESEARCHERS OF REPETITIVE TASKS AND FREE THEM FOR MORE CREATIVE WORK. FURTHER BENEFITS WILL ACCRUE AS ADDITIONAL TOOLS BECOME AVAILABLE TO ANALYZE DNA SEQUENCES AND TO PREDICT THE FUNCTIONS OF THE SUBSTANCES FOR WHICH THEY CODE.

COST HAS BEEN THE PRIMARY BARRIER IN DEVELOPING A COMPLETE GENETIC MAP AND SEQUENCE OF DNA, BUT THE NECESSARY MAPPING TECHNOLOGY AND ITS COST HAVE BEEN CHANGING RAPIDLY. FOR THAT REASON, THE DEPARTMENT OF ENERGY HAS PROPOSED A CONCERTED EFFORT TO DEVELOP TECHNOLOGY FURTHER TO REDUCE THE COST OF BOTH MAPPING AND SEQUENCING. THE DEPARTMENT HAS A PROVEN ABILITY TO CARRY OUT TECHNOLOGY DEVELOPMENT PROGRAMS LIKE THIS ONE.

THE DEPARTMENT IS LAYING OUT A PROGRAM PLAN TO DESCRIBE ITS APPROACH FOR DEVELOPING THESE TECHNOLOGIES. THAT APPROACH WOULD EMPLOY THE MULTIDISCIPLINARY CAPABILITIES OF THE DOE NATIONAL LABORATORIES AND DRAW ON OTHER FEDERAL AGENCIES, THE ACADEMIC COMMUNITY, AND THE PRIVATE SECTOR. IN KEEPING WITH GOOD PROGRAM PRACTICE, AND CONSISTENT WITH THE PRESIDENT'S COMPETITIVENESS INITIATIVE, THE PROGRAM PLAN WILL IDENTIFY OPPORTUNITIES FOR PRIVATE SECTOR INVOLVEMENT IN PROGRAM PLANNING, EVALUATION, AND EXECUTION, SO AS TO ENSURE THE MOST EFFECTIVE TRANSFER OF TECHNOLOGY TO THE PRIVATE SECTOR. TECHNOLOGY DEVELOPED WITHIN THE HUMAN GENOME INITIATIVE CAN BE TRANSFERRED TO THE PRIVATE SECTOR VERY EFFECTIVELY USING EXISTING MECHANISMS.

THE SUCCESS OF THE HUMAN GENOME INITIATIVE WILL BE VALUABLE NOT ONLY TO DOE IN ITS RESPONSIBILITIES FOR ENERGY-RELATED HEALTH AND ENVIRONMENT EFFECTS, BUT TO NUMEROUS INVESTIGATORS SUPPORTED BY THE NATIONAL INSTITUTES OF HEALTH, MANY OF WHOM NOW MUST CARRY OUT MAPPING AND SEQUENCING PROCEDURES. NIH CONTINUES TO SUPPORT RESEARCH ON GENETICS OF HUMAN DEVELOPMENT AND IS ENGAGED IN AN EFFORT TO LOCATE THOSE GENES RESPONSIBLE FOR HUMAN DISABILITIES. NIH FUNDS ABOUT 3,000 RESEARCH PROJECTS RELATED TO GENE ELUCIDATION AND WILL CONTINUE TO PROVIDE SUPPORT FOR THESE AND OTHER HUMAN GENOME MAPPING PROJECTS.

THE THREE AGENCIES INVOLVED IN RESEARCH RELATED TO THE HUMAN GENOME INITIATIVE--DOE, NIH, AND NSF--HISTORICALLY HAVE HAD COMPLEMENTARY ROLES. COORDINATION AMONG AGENCIES ON THIS INITIATIVE HAS BEEN FACILITATED BY THE EXECUTIVE OFFICE OF THE PRESIDENT, AND MECHANISMS EXIST WITHIN THE OFFICE TO CONTINUE COORDINATION OF THESE COMPLEMENTARY EFFORTS AND TO INVOLVE THE PRIVATE SECTOR. PRIVATE SECTOR INVOLVEMENT IS IMPORTANT TO COST-EFFECTIVE EXECUTION OF THE INITIATIVE AND IS CRITICAL TO EFFECTIVE TECHNOLOGY TRANSFER.

THE COORDINATION AMONG ALL THE AGENCIES TO IDENTIFY PROMISING TECHNIQUES SUITABLE FOR EVALUATION AS PART OF THE TECHNOLOGY DEVELOPMENT PROGRAM AND TO IDENTIFY NEEDS OF RESEARCHERS WILL CONTRIBUTE TO THE SUCCESS OF THE INITIATIVE. IN ADDITION TO THE NIH ACTIVITIES REFERRED TO ABOVE, NIH IS EXPECTED TO CONTINUE TO PLAY AN IMPORTANT ROLE IN SUPPORTING THE DNA-SEQUENCE DATABASE, WHICH IS KNOWN AS GENBANK, ALONG WITH NSF AND DOE AND IN SUPPORTING DEVELOPMENT OF A SYSTEM FOR MAKING THE RESULTS OF THE MAPPING EFFORT AVAILABLE TO ALL INVESTIGATORS. COORDINATION WITH THE NATIONAL SCIENCE FOUNDATION WILL ENHANCE DEVELOPMENT OF MATHEMATICAL TECHNIQUES FOR ANALYZING DNA SEQUENCES AND FOR DEVELOPING TECHNIQUES TO PREDICT THE FUNCTIONS OF A PROTEIN FROM ITS DNA SEQUENCE.

IN SUMMARY, THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY SUPPORTS THE HUMAN GENOME INITIATIVE AS PROPOSED IN THE ADMINISTRATION'S FY 1988 BUDGET BECAUSE OF ITS POTENTIAL FOR IMPROVING THE COMPETITIVENESS OF AMERICAN INDUSTRY AND ADVANCING SCIENCE IN AREAS THAT DIRECTLY AFFECT OUR LIVES. IN VIEW OF THIS STRONG ADMINISTRATION SUPPORT, AND EXISTING LEGISLATIVE AUTHORITY, WE DO NOT BELIEVE THAT ADDITIONAL AUTHORIZING LEGISLATION IS NEEDED TO CARRY OUT THIS INITIATIVE.

TITLE III - SEMICONDUCTOR INITIATIVE:

IN DISCUSSING TITLE III OF THE BILL, I WILL BEGIN BY STATING THAT I AM IN FULL AGREEMENT WITH SENATOR DOMENICI AS TO THE CRITICAL IMPORTANCE OF THE SEMICONDUCTOR INDUSTRY TO OUR ECONOMIC AND NATIONAL SECURITY. TWO STUDIES CARRIED OUT FOR THE GOVERNMENT--BY THE DEFENSE SCIENCE BOARD AND THE WHITE HOUSE SCIENCE COUNCIL--CLEARLY SUPPORT THIS NOTION. THE CRITICAL QUESTION CONCERNING THE COMPETITIVENESS OF THE SEMICONDUCTOR INDUSTRY, ESPECIALLY WITH RESPECT TO MANUFACTURING TECHNOLOGY -- WHAT IS THE APPROPRIATE ROLE FOR THE GOVERNMENT? THIS ISSUE IS NOW UNDER REVIEW WITHIN THE ADMINISTRATION.

TITLE III OF THE BILL FOCUSES ON A "SEMICONDUCTOR TECHNOLOGY MANUFACTURING EXCELLENCE INITIATIVE," WHICH TRACKS IN MANY WAYS WITH SEMATECH, THE INDUSTRY CONSORTIUM BEING FORMED TO DEVELOP AND IMPROVE U.S. SEMICONDUCTOR MANUFACTURING TOOLS AND METHODS.

MY STAFF AND I HAVE SPENT CONSIDERABLE TIME WITH THE SEMATECH DEVELOPERS, BOTH IN WASHINGTON AND AT SEVERAL WORKSHOPS THEY HAVE SPONSORED WITH INDUSTRY AND THE NATIONAL LABORATORIES. AS A RESULT OF THE MANY DISCUSSIONS WE HAVE HAD, I BELIEVE THAT IT IS A GOOD IDEA--ONE THAT WILL HELP THE INDUSTRY IN AN AREA WHERE JAPANESE CORPORATIONS HAVE IN THE RECENT PAST PROVED SUPERIOR--THAT IS IN MUCH OF THE AREA OF SEMICONDUCTOR MANUFACTURING TECHNOLOGY. IN THIS REGARD AND BECAUSE OF THE IMPORTANT ISSUE OF GOVERNMENT FUNDING, SEMATECH HAS BEEN GIVEN CONSIDERABLE ATTENTION. HOWEVER, AS POINTED OUT BY THE WHITE HOUSE SCIENCE COUNCIL AND BY MANY WITHIN THE SEMICONDUCTOR INDUSTRY, NO SINGLE ACTION CAN SUCCESSFULLY ADDRESS ALL THE FACTORS THAT MUST BE REMEDIED TO IMPROVE THE INDUSTRY'S LONG-TERM INTERNATIONAL COMPETITIVENESS.

IT IS THE LONG-STANDING POLICY OF THE FEDERAL GOVERNMENT TO SUPPORT BASIC SCIENTIFIC RESEARCH, INCLUDING BASIC RESEARCH IN ENABLING TECHNOLOGIES -- THOSE TECHNOLOGIES NECESSARY TO ENABLE COMMERCIAL APPLICATIONS OF ADVANCED TECHNOLOGY. THE ADMINISTRATION IS CONSIDERING WHETHER ADDITIONAL MEASURES SHOULD BE TAKEN TO PROMOTE ENABLING TECHNOLOGIES IN THE SEMICONDUCTOR AREA. THE SEMATECH INITIATIVE, WHILE IMPORTANT, GOES BEYOND BASIC RESEARCH INTO THE APPLIED AREA. IN MY JUDGMENT IT IS NOT APPROPRIATE FOR NON-DEFENSE AGENCIES OF THE FEDERAL GOVERNMENT TO PROVIDE SUPPORT IN APPLIED RESEARCH TO SPECIFIC COMMERCIAL SECTORS OF THE ECONOMY. IT MAY BE, HOWEVER, APPROPRIATE FOR THE DEPARTMENT OF DEFENSE TO SUPPORT SEMATECH OR SIMILAR INITIATIVES THAT MEET DOD REQUIREMENTS TO ENSURE OUR NATIONAL SECURITY AT THE LOWEST POSSIBLE OVERALL COST.

I BELIEVE DOD HAS EARMARKED $50 MILLION IN ITS FY-88 BUDGET FOR MANUFACTURING METHODS FOR SEMICONDUCTORS USED IN WEAPONS SYSTEMS. I AM CONCERNED, HOWEVER, WITH PROPOSED ADDITIONAL APPROPRIATIONS TO THE DEPARTMENT OF ENERGY TO BE USED FOR SEMATECH, UNLESS IT IS PART OF BASIC RESEARCH INCLUDING "ENABLING" TECHNOLOGY, OR IT CAN BE DEMONSTRATED THAT SUCH FUNDS WILL SUPPORT THE NATIONAL SECURITY MISSION OF THE DOE, AS IS THE CASE WITH SANDIA NATIONAL LABORATORY'S RADIATION-HARDENED SEMICONDUCTOR PROGRAM.

S.1480 EMPHASIZES THE ROLE OF THE DOE NATIONAL LABORATORIES, CONCERNING A SEMICONDUCTOR MANUFACTURING INITIATIVE. THE BILL STATES THAT AN ESSENTIAL PART OF EACH DOE NATIONAL LABORATORY'S MISSION WILL BE PARTICIPATION IN R&D PROJECTS IN CONJUNCTION WITH DOE AND INDUSTRY CONSORTIA. I BELIEVE THAT SEVERAL APPROPRIATE NATIONAL LABORATORIES ARE ALREADY PLAYING A CONSTRUCTIVE ROLE IN FURTHERING OUR COMPETITIVENESS IN THE SEMICONDUCTOR AREA. CURRENTLY THERE ARE A NUMBER OF COOPERATIVE PROGRAMS WITH INDUSTRY. FOR EXAMPLE, DOE HAS JUST INITIATED AN INDUSTRY-UNIVERSITY PROGRAM ON MATERIALS PROCESSING AT THE OAK RIDGE NATIONAL LABORATORY.

WHILE I FAVOR THE NATIONAL LABORATORIES BECOMING MORE INVOLVED IN BASIC RESEARCH THAT COULD BENEFIT OUR INDUSTRIAL COMPETITIVENESS, I AM CONCERNED THAT SUCH ACTIVITY NOT BE AT THE EXPENSE OF THEIR PRIMARY MISSION REQUIREMENTS. EXCHANGE OF INFORMATION BETWEEN THE NATIONAL LABORATORIES AND INDUSTRY SHOULD BE ENCOURAGED, WITH THE CAUTION THAT SPECIAL PROGRAMS IN THE LABORATORIES AIMED AT COMMERCIAL OBJECTIVES SHOULD BE CAREFULLY REVIEWED, SO AS NOT TO TAX THEIR PRIMARY ABILITY TO FULFILL THEIR MISSION OBJECTIVES. FURTHERMORE, BECAUSE THE INDUSTRY HAS MUCH TO GAIN FROM COOPERATIVE PROGRAMS WITH THE NATIONAL LABORATORIES, I BELIEVE, CONSISTENT WITH THE PROPOSED LANGUAGE, THAT INDUSTRY SHOULD BEAR PART OF THE COSTS.

TITLE IV - ENTREPRENEURIAL STUDIES:

I BELIEVE THAT IT IS IMPORTANT FOR UNIVERSITIES TO ALLOW OR EVEN ENCOURAGE PROFESSORS TO BE ENTREPRENEURS IF THEY ARE SO INCLINED AND IF CONSISTENT WITH THEIR OTHER DUTIES, AND TO DEVELOP PROGRAMS WHEREBY STUDENTS ARE ENCOURAGED TO BECOME ENTREPRENEURS. I AM CONCERNED, HOWEVER, ABOUT THE NOTION OF THE FEDERAL GOVERNMENT PRESCRIBING TO THE UNIVERSITIES HOW THEY SHOULD ACCOMPLISH THIS GOAL. IF ONE EXAMINES THE RESEARCH PARKS THAT CONTINUE TO SPRING UP AROUND OUR BEST RESEARCH UNIVERSITIES, ONE HAS TO BELIEVE THAT THEY KNOW SOMETHING ABOUT THIS PROCESS.

S.1480 NOT ONLY PRESCRIBES A STRONG ASSOCIATION BETWEEN ENTREPRENEURS AND THE DEPARTMENT OF ENERGY LABORATORIES, BUT IT ALSO PRESCRIBES THE CURRICULUM FOR BOTH PUBLIC AND PRIVATE UNIVERSITIES IN ENTREPRENEURIAL STUDIES. I HAVE DIFFICULTY CONCEIVING OF THE FEDERAL GOVERNMENT'S ADVISING UNIVERSITIES ABOUT HOW TO EDUCATE FUTURE ENTREPRENEURS IN WAYS TO BECOME ENTREPRENEURIAL. THIS SURELY SHOULD BE LEFT TO THE REAL EXPERTS--THE U.S. ENTREPRENEURS. I THEREFORE RECOMMEND CONSIDERING DELETION OF TITLE IV FROM S.1480.

FINAL REMARKS:

I HAVE TRIED TO MAKE MY COMMENTS AS CONSTRUCTIVE AS POSSIBLE, AS I HAVE FOUND MANY AREAS OF AGREEMENT WITHIN THE FIRST THREE TITLES AND SEVERAL AREAS WHERE PROPOSED PROGRAMS ARE ALREADY BEING IMPLEMENTED. I LOOK FORWARD TO CONTINUING TO WORK WITH SENATOR DOMENICI AND THIS SUBCOMMITTEE TOWARD THE IMPORTANT GOALS WE SHARE.

MR. CHAIRMAN, I AM NOW PREPARED TO ANSWER QUESTIONS.

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The Argonne National Laboratory-The University of Chicago Development Corporation (ARCH) was formed in 1986 to facilitate the commercial development of scientific and technical intellectual property originating at the university and national laboratory. The primary function of ARCH is to move discoveries from these world-renowned institutions to the marketplace.

ARCH is the first development corporation in the nation to capitalize on the combined resources of a major university and a major national laboratory. It provides commercial developers with access to discoveries from combined science and research budgets totaling more than $380 million annually.

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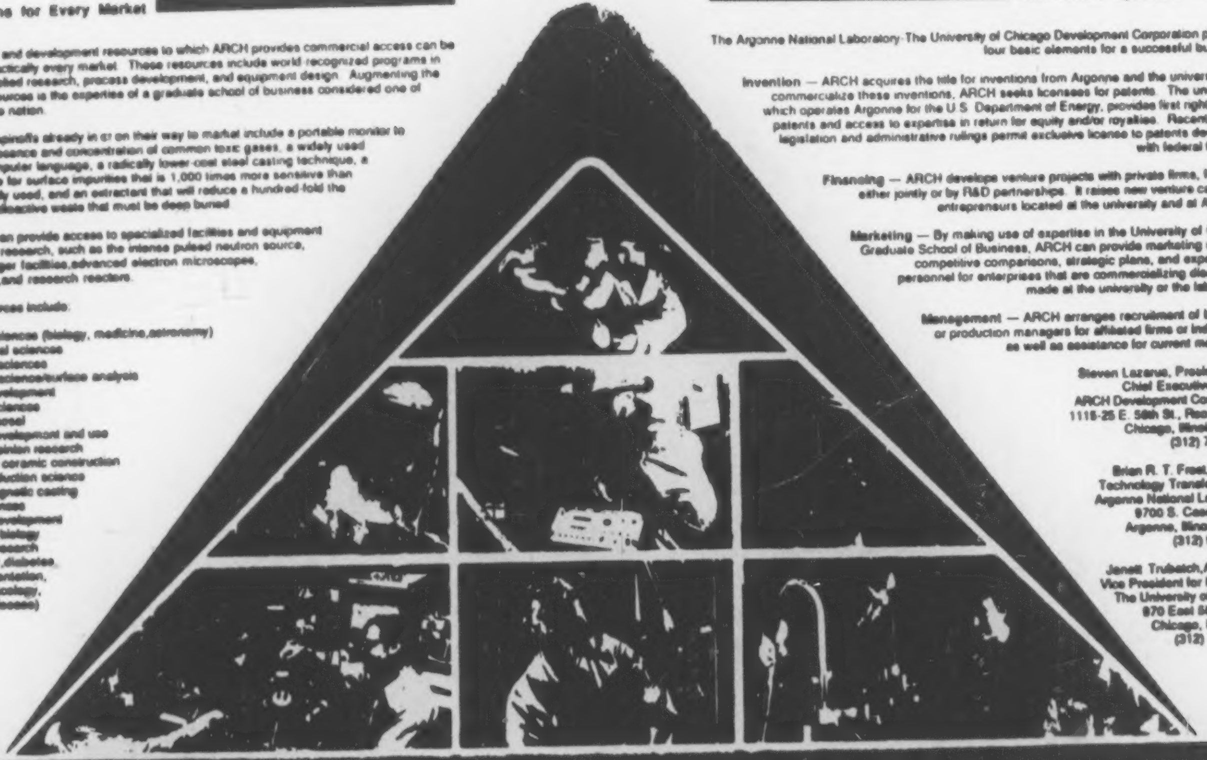

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The Argonne National Laboratory-The University of Chicago Development Corporation provides four basic elements for a successful business.

Invention — ARCH acquires the title for inventions from Argonne and the university. To commercialize these inventions, ARCH seeks licensees for patents. The university, which operates Argonne for the U.S. Department of Energy, provides first rights to the patents and access to expertise in return for equity and/or royalties. Recent federal legislation and administrative rulings permit exclusive license to patents developed with federal funding.

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Senator FORD. Thank you, Dr. Graham.

Dr. Nicholson?

STATEMENT OF DR. RICHARD S. NICHOLSON, ASSISTANT DIRECTOR, MATHEMATICAL AND PHYSICAL SCIENCE DIRECTORATE, NATIONAL SCIENCE FOUNDATION

Dr. NICHOLSON. Thank you, Mr. Chairman. It is a real pleasure to be here and tell you a little bit about the activities of the National Science Foundation in the area of superconductivity.

I have a detailed written statement which, with your permission, I would like to submit for the record and just give you a four or five minute summary.

Senator FORD. That would be great.

Without objection, your statement will be included in the record in total.

Dr. NICHOLSON. As you can probably imagine, Mr. Chairman, the National Science Foundation is kind of proud of the role that it has played so far in the area of superconductivity and the exciting discoveries that have been made. I think it is pretty well known by now that the solid state physics program in the Division of Materials Research at the National Science Foundation provided the sustained support for Dr. Paul Chu at the University of Houston over a period of some 14 years as he labored in the area of superconductivity, and in fact, this past year at the time of the discovery, Dr. Chu was actually working in our place at 1800 G Street on a temporary assignment from the University of Houston. So we at NSF were able to be very much on top of the events as they were breaking.

As Paul Chu himself will tell you, it was really the sustained support—emphasize the word "sustained"—that NSF was able to provide over this long period of time that enabled him to evolve the expertise, assemble the equipment, put together the laboratory and the group of students and other collaborators to put him in a position where he was able to make this discovery.

I think this experience with superconductivity in a broader sense in fact illustrates and reaffirms the wisdom of the system we have in our country for supporting scientific research, where both mission agencies like the Department of Energy that we are talking about today, and this one special agency, the National Science Foundation, both have responsibilities for supporting basic research and science. We are really in a sense——

Senator DOMENICI. Could I ask a question?

Senator FORD. Any time.

Senator DOMENICI. Let me just ask, and I think you must know that I know the answer, but anyway, I am going to ask you——

Senator FORD. That is a very sensitive question now, asking you a question that he knows the answer to.

Senator DOMENICI. This sustained effort that you speak of, there is no entitlement out there, is there?

Dr. NICHOLSON. No, sir. As I was about to say, in fact, it is really, in a sense, you could say what the NSF's criterion is is scientific excellence, and if a person can meet that criterion year after year, then we are able to support them, and that was exactly the case with Dr. Chu. He was able to meet that criterion of scientific excellence over that period of time, and working in an area where no one, I mean, absolutely no one, Mr. Chairman, a year ago would have predicted that this was going to happen. It was not supported because someone thought a breakthrough was about to occur. It was supported because NSF emphasizes excellence as its principal criterion of support.

In fact, I think it is the sheer improbability of this discovery of high temperature superconductors and in ceramics, no less, not in metals but in ceramics, the sheer improbability of that is what has so stunned and has captivated the scientific community worldwide. It was absolutely an unexpected thing. It is also precisely because of this kind of unique character of the National Science Foundation and the fact that we know that scientific discoveries like this cannot be preordained, we cannot say they are going to happen next year, that we were able to encourage our grantees, the people who are able to pass this excellence criterion, we encourage them to do what you might call follow their scientific noses. That is, when they discover something that looks especially exciting, we encourage them to pursue it.

This is what made it possible in the first instance for Dr. Chu to move very quickly into looking at ceramics materials when the first hints came that this would be a profitable thing to do. And since then it has made it possible for a large number of our grantees, without a lot of bureaucratic red tape, to shift into the area of superconductivity over the last few months.

In addition to that, the National Science Foundation has taken the following actions. We quickly identified three of the ten materials research laboratories that are supported by the National Science Foundation. We looked for ones that had the right mix of physicists, chemists and ceramicists to work on materials processing aspects of this breakthrough because that is where a lot of the really tough problems are. We identified three of these laboratories and reprogrammed already a total of $1 million into those three centers.

We also reprogrammed some $600,000 in engineering to provide sort of what we are calling quick start grants to engineers across the country who have been invited to come to the National Science Foundation with novel ideas for processing, trying to process the superconducting materials.

A third thing we did is we asked the National Research Council of the National Academy of Sciences through its committee on Science, Engineering and Public Policy, to add a briefing on superconductivity to the so-called research briefings that the National Research Council annually provides to some of the R&D agencies in the executive branch. These are briefings traditionally started by Jay Keyworth several years ago at the time that he was the President's Science Advisor.

This report from the National Research Council will be issued on Friday of this week. I have seen a preview of it, and I believe it is excellent. I think all of us will find it to be a very useful and provocative document. It accurately and very succinctly—it is only about 30 pages long—summarizes the current status of the field, and importantly, I think it puts both the fantastic potential for opportunities that exist, but as well as the really tough R&D problems that we have to overcome in order to realize those activities, it puts both of those in a really good perspective.

The report identifies several specific technological objectives that we should pursue, and it also offers policy recommendations. In particular, the National Research Council shares our concern that the infectious enthusiasm in the press and elsewhere recently about superconductivity, while quite understandable, may be causing premature public expectations that revolutionary technologies are going to occur on a very short time scale.

In fact, Mr. Chairman, I think the reality is that the scientific and technological problems that remain to be solved are such that all of us in this country must be committed to a very long term and sustained effort.

The National Research Council also notes the important role that interdisciplinary research centers can and should play in this area. President Reagan and Dr. Graham previously and Dr. Graham just a few minutes ago have called for the government R&D agencies to establish science and technology centers which are not unlike really the cooperative research centers contained in Title I of this bill S. 1408. I am pleased to tell you that just this week the National Science Foundation has issued a program announcement soliciting the first round of these proposals.

While we have decided as a matter of policy not to preselect the areas that the centers will be in, it is really inconceivable, I think, that some of the new centers will not be in the area of superconductivity. I think it is also quite possible that some of the best proposals will involve partnerships with National Laboratories and the private sector.

Mr. Chairman, this completes my brief summary of the status of the NSF reactions to the bill.

[The prepared statement of Dr. Nicholson follows:]

REMARKS
DR RICHARD S. NICHOLSON

ASSISTANT DIRECTOR, NATIONAL SCIENCE FOUNDATION

BEFORE THE

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

OF THE

SENATE ENERGY AND NATURAL RESOURCES COMMITTEE

TUESDAY, SEPTEMBER 15, 1987

GOOD AFTERNOON. I APPRECIATE THE OPPORTUNITY TO DISCUSS WITH YOU NSF ACTIVITIES RELATED TO SUPERCONDUCTIVITY. RECENT SCIENTIFIC ADVANCES IN THIS FIELD HAVE EXCITED TREMENDOUS INTEREST IN POSSIBLE APPLICATIONS OF SUPERCONDUCTIVITY IN THE MEDIA, IN THE TECHNOLOGICAL COMMUNITY, IN THE PUBLIC, AND THROUGHOUT THE GOVERNMENT. FOR EXAMPLE, THE RECENT FEDERAL CONFERENCE ON COMMERCIAL APPLICATIONS OF SUPERCONDUCTIVITY WAS ATTENDED BY OVER 1100 LEADERS OF THE SCIENTIFIC AND BUSINESS COMMUNITIES.

THERE IS GOOD REASON FOR THIS EXCITEMENT. ALTHOUGH THE COMMERCIAL APPLICATIONS OF SUPERCONDUCTIVITY MAY BE YEARS IN THE FUTURE, THEIR SIGNIFICANCE WILL UNDOUBTEDLY BE GREAT.

BUT IT IS WELL TO KEEP IN MIND THAT WHAT HAS BEEN ACCOMPLISHED SO FAR IS LARGELY BASIC RESEARCH. WE ARE RAPIDLY LEARNING MORE ABOUT THE MATERIALS AND THEIR CHARACTERISTICS, AND ABOUT SUPERCONDUCTIVITY ITSELF. WE ARE ALSO LEARNING ABOUT THE MANY TECHNICAL PROBLEMS THAT WILL HAVE TO BE SOLVED BEFORE WE CAN PUT SUPERCONDUCTIVITY TO WIDESPREAD PRACTICAL USE.

WE MAY SOLVE SOME OF THESE PROBLEMS RAPIDLY. MANY, HOWEVER, WILL TAKE YEARS OF FURTHER RESEARCH AND DEVELOPMENT BEFORE USEFUL PRODUCTS CAN BE CREATED.

I WOULD LIKE TO START WITH A BRIEF REVIEW OF THE FOUNDATION'S SUPPORT FOR RESEARCH RELATED TO SUPERCONDUCTIVITY.

THE NATIONAL SCIENCE FOUNDATION HAS BEEN A CONSISTENT SUPPORTER OF RESEARCH RELATED TO SUPERCONDUCTIVITY FOR MANY YEARS, PRIMARILY THROUGH THE LOW TEMPERATURE PHYSICS, CONDENSED MATTER THEORY, AND MATERIALS RESEARCH LABORATORIES PROGRAMS OF THE DIVISION OF MATERIALS RESEARCH, AND THROUGH THAT DIVISION'S FUNDING FOR THE NATIONAL MAGNET LABORATORY. PAUL CHU, WHOSE

LABORATORY AT THE UNIVERSITY OF HOUSTON HAS PRODUCED MUCH OF THE CURRENT EXCITEMENT, HAS BEEN STEADILY SUPPORTED BY NSF SINCE 1973. THERE WAS NEVER A POINT DURING THOSE FOURTEEN YEARS OF SUPPORT AT WHICH THE RECENT ADVANCES COULD HAVE BEEN PREDICTED. BUT CHU'S HARD, PERSISTENT WORK HAS CONSISTENTLY BEEN RATED HIGHLY BY HIS PEERS.

IN RECENT YEARS THE FOUNDATION HAS PROVIDED ABOUT $4 MILLION ANNUALLY FOR SUPERCONDUCTIVITY RESEARCH. IN THE CURRENT YEAR WE ESTIMATE THAT THIS SUPPORT HAS MORE THAN DOUBLED.

PART OF THE INCREASE IS THE RESULT OF SPECIFIC ACTIONS: THE MATERIALS RESEARCH LABS HAVE SHIFTED A MILLION DOLLARS TO SUPERCONDUCTIVITY RESEARCH, AND ANOTHER MILLION HAS BEEN PROVIDED FROM OTHER SOURCES.

IN THE ENGINEERING DIRECTORATE, A $600,000 EFFORT HAS STARTED TO IMPROVE PROCESSING CAPABILITY. PROCESSING IS OBVIOUSLY CRITICAL BEFORE APPLICATIONS OF THESE NEW MATERIALS CAN EVEN BE CONSIDERED.

MUCH OF THE INCREASED ACTIVITY, HOWEVER, IS THE RESULT OF INDIVIDUAL DECISIONS BY INVESTIGATORS TO SHIFT THEIR RESEARCH PROGRAMS TO TAKE ADVANTAGE OF THE NEW OPPORTUNITIES. THIS HAS BEEN DONE ON THE BASIS OF INDIVIDUAL INITIATIVE, WITHOUT FOUNDATION INVOLVEMENT.

THIS IS ONE OF THE GREAT STRENGTHS OF THE FLEXIBLE SYSTEM THAT WE USE TO SUPPORT RESEARCH. WHEN IMPORTANT NEW LINES OF INVESTIGATION OPEN UP THE SYSTEM RESPONDS ON ITS OWN INITIATIVE, AND MUCH MORE RAPIDLY THAN IT COULD IF IT WERE DEPENDENT ON DECISIONS MADE THROUGH A BUREAUCRATIC STRUCTURE IN WASHINGTON.

BEFORE THE MATERIALS CAN BE USED, HOWEVER, WE MUST LEARN TO MAKE THEM INTO FORMS SUCH AS WIRES AND FILMS AND AT THE SAME TIME TO IMPROVE THEIR ABILITY TO CARRY LARGE CURRENTS OR WITHSTAND HIGH MAGNETIC FIELDS. ONLY WHEN THIS IS POSSIBLE WILL WE BE ABLE TO SPEAK REALISTICALLY OF IMPROVED POWER GENERATION AND TRANSPORT, OF USING MAGNETS FOR POWER STORAGE OR FOR NUCLEAR FUSION, OR OF LEVITATED TRAINS, MORE POWERFUL ACCELERATORS, AND ELECTRONIC CIRCUITS.

SUPERCONDUCTIVITY RESEARCH SUPPORTED BY OTHER AGENCIES INCLUDES BOTH BASIC AND APPLIED WORK. OVERALL, IT APPEARS THAT THE FEDERAL GOVERNMENT IS SUPPORTING ABOUT $30 MILLION IN THE CURRENT FISCAL YEAR FOR BASIC RESEARCH IN SUPERCONDUCTIVITY, WITH ADDITIONAL AMOUNTS FOR APPLICATIONS. THE BASIC RESEARCH PORTION APPEARS TO HAVE ROUGHLY DOUBLED SINCE LAST YEAR.

WITH RESPECT TO INDUSTRY WE KNOW THAT THE EFFORT IS LARGE, BUT WE HAVE NO COMPREHENSIVE DATA. WE KNOW THAT AT&T, DUPONT, GE, IBM, AND WESTINGHOUSE ALL HAVE SIGNIFICANT PROGRAMS UNDERWAY, AND THAT

MANY SMALLER COMPANIES ARE INVOLVED. PERHAPS AS MANY AS 400 SCIENTISTS ARE INVOLVED AT THE LARGER COMPANIES.

OBVIOUSLY INDUSTRY HAS A LONG HISTORY IN THIS FIELD. IN FACT THE EARLY DISCOVERIES OF THE IBM-ZURICH LAB IN JANUARY 1986 TRIGGERED ALL THE WORK AND THE DISCOVERIES OF THE LAST SIX MONTHS.

WE ALSO KNOW THAT THERE IS A GREAT DEAL OF WORK GOING ON IN OTHER COUNTRIES.

THE OVERALL PICTURE, THEN, IS ONE OF A LARGE AND RAPIDLY GROWING RESEARCH EFFORT. THE BASIC CAPACITY TO ENGAGE IN THIS KIND OF RESEARCH EXISTS IN MANY INSTITUTIONS IN MANY COUNTRIES, AND THUS WE CAN EXPECT TO SEE MORE GROUPS BECOMING ACTIVE AS TIME GOES ON. ONE CAN SAY WITH CONFIDENCE THAT THERE WILL BE MANY PLAYERS IN THIS GAME.

THERE WILL CONTINUE TO BE RAPID PROGRESS ON IMPORTANT SCIENTIFIC ISSUES. NUMEROUS RESEARCH GROUPS HAVE REPORTED TANTALIZING HINTS OF SUPERCONDUCTIVITY AT TEMPERATURES ABOVE 200 K.

THERE HAVE ALSO BEEN IMPORTANT ANNOUNCEMENTS FROM INDUSTRIAL AND OTHER GROUPS CONCERNING THE CURRENT-CARRYING CAPACITY OF THESE NEW MATERIALS, AND OF THEIR ABILITY TO WITHSTAND VERY HIGH MAGNETIC FIELDS. THERE WILL BE MANY MORE SUCH REPORTS IN THE MONTHS TO COME.

WE NEED TO MONITOR THE SITUATION CONTINUALLY, SO THAT WE CAN KEEP POLICY-MAKERS AWARE OF THE TECHNICAL DEVELOPMENTS AND THEIR SIGNIFICANCE. THIS IS NOT EASY, BECAUSE THE SITUATION IS CHANGING SO RAPIDLY. IT MUST BE A CONTINUING EFFORT, ALTHOUGH IT WILL BE PUNCTUATED WITH PERIODIC SUMMARY REPORTS FROM ADVISORY COMMITTEES AND OTHER GROUPS.

NSF HAS ASKED THE NATIONAL ACADEMIES TO INCLUDE SUPERCONDUCTIVITY AS AN EXTRA SUBJECT IN THIS YEAR'S SERIES OF RESEARCH BRIEFINGS. THIS BRIEFING IS BEING PREPARED NOW BY A COMMITTEE OF DISTINGUISHED RESEARCHERS IN THE FIELD CHAIRED BY DR. JOHN HULM OF WESTINGHOUSE, AND WILL BE AVAILABLE SOON.

OTHER MECHANISMS FOR CONTINUING ASSESSMENT AND COORDINATION ARE THE VARIOUS COMMITTEES ORGANIZED UNDER THE WHITE HOUSE SCIENCE COUNCIL, FCCSET, AND THE EPC, WHICH ARE CURRENTLY REVIEWING GOALS AND MECHANISMS FOR COORDINATING THE EFFORTS OF THE VARIOUS AGENCIES. OF PARTICULAR NOTE IS THE "WISE MEN" ADVISORY GROUP RECENTLY ESTABLISHED UNDER THE ASUPICES OF THE WHITE HOUSE SCIENCE COUNCIL TO ADVISE THE ADMINISTRATION ON RESEARCH AND COMMERCIALIZATION POLICIES.

IN ADDITION TO THESE MAJOR POLICY DISCUSSIONS, THERE ARE MANY MORE SPECIALIZED ACTIVITIES. DOE HAS ARRANGED SEVERAL DISCUSSIONS AMONG DOE LABS AT ARGONNE NATIONAL LABORATORY, AND

THREE MEETINGS IN WASHINGTON WHICH INCLUDED REPRESENTATIVES OF OTHER AGENCIES.

DURING THE SPRING AND SUMMER THERE HAVE BEEN SPECIAL SESSIONS ON SUPERCONDUCTIVITY AT MEETINGS OF THE AMERICAN PHYSICAL SOCIETY, THE MATERIALS RESEARCH SOCIETY, THE NATIONAL ACADEMY OF SCIENCES, AND THE AMERICAN CHEMICAL SOCIETY. IN MAY NSF HELD A PLANNING MEETING TO BEGIN THINKING ABOUT THE POSSIBILITY OF UNDERGROUND TRANSMISSION LINES, AND IN JUNE THE DOE SPONSORED A MAJOR INTERNATIONAL CONFERENCE ON MECHANISMS OF SUPERCONDUCTIVITY IN BERKELEY. ANOTHER SUPERCONDUCTIVITY CONFERENCE WAS HELD AT DREXEL, AND IN AUGUST SUPERCONDUCTIVITY WAS THE MAJOR FOCUS OF THE 18TH INTERNATIONAL CONFERENCE ON LOW TEMPERATURE PHYSICS IN KYOTO.

THE POINT OF ALL THIS IS THAT A HIGH LEVEL OF INFORMATION EXCHANGE ALREADY EXISTS. SCIENTISTS AND ENGINEERS ARE DOING EVERYTHING THEY CAN TO STAY ABREAST OF DEVELOPMENTS, BECAUSE THEY MUST IF THEIR RESEARCH IS TO STAY PROPERLY DIRECTED. AND IN THE GOVERNMENT, THE FUNDING AGENCIES ARE CONSTANTLY REASSESSING THEIR PLANS IN THE LIGHT OF NEW FINDINGS.

IN THIS CONTEXT, THE PROPOSAL TO CREATE A SPECIAL COUNCIL FOR RESEARCH ON ENABLING TECHNOLOGIES MAY BE UNNECESSARY.

INSTEAD, LET'S USE THE EXISTING MECHANISMS PROPERLY: MEETINGS, SEMINARS, AND EXCHANGES BETWEEN LABORATORIES.
WE SHOULD HAVE PERIODIC REVIEWS BY THE INSTITUTIONS CHARTERED BY THE GOVERNMENT FOR THIS PURPOSE: THE NATIONAL ACADEMIES OF SCIENCE AND ENGINEERING AND THE COMMITTEES OF THE NATIONAL RESEARCH COUNCIL.

WHAT SHOULD WE BE DOING TO EXPLOIT THE SUPERCONDUCTIVITY BREAKTHROUGH?

THE FIRST PART OF THE ANSWER LIES IN UNDERSTANDING THE PROPER ROLES OF THE AGENCIES, UNIVERSITIES, AND INDUSTRY.

NSF'S ROLE, PARADOXICALLY, IS AS MUCH IN THE PAST AS IN THE FUTURE. THE FOUNDATION'S MOST IMPORTANT CONTRIBUTION IS STEADY, BROAD SUPPORT ACROSS ALL THE SCIENCES AND ENGINEERING, BECAUSE ONE SIMPLY CANNOT KNOW WHERE THE NEXT MAJOR BREAKTHROUGH WILL COME FROM. FOR FOURTEEN YEARS NSF SUPPORTED PAUL CHU, AND OTHER RESEARCHERS LIKE HIM, IN THE SURE KNOWLEDGE THAT SOME WOULD MAKE MAJOR ADVANCES, AND ALL WOULD CONTRIBUTE INSIGHTS THAT WOULD ADD TO OUR UNDERSTANDING OF NATURE.

EXPLOITATION OF A BREAKTHROUGH, HOWEVER, IS THE RESPONSIBILITY OF THE PRIVATE SECTOR. NSF WILL CONTINUE TO SUPPORT A BROAD RANGE OF BASIC RESEARCH AT UNIVERSITIES. BUT WE BELIEVE IT IS BEST THAT DOE'S NATIONAL LABS SHOULD PLAY THEIR TRADITIONAL ROLE

INTERACTING WITH INDUSTRY AS THE WORK BECOMES MORE APPLIED AND DIRECTED. THE LEVEL OF EFFORT IN INDUSTRY ITSELF WILL RISE AS SPECIFIC PRODUCTS BECOME MORE PREDICTABLE.

IN ADDITION, AS RECOGNIZED IN THE PRESIDENT'S SUPERCONDUCTIVITY INITIATIVE, THE NATIONAL LABS CAN PROVIDE A SPECIAL FOCUS TO THIS ACTIVITY, BOTH THROUGH THEIR OWN RESEARCH AND BY SERVING AS INFORMATION NODES THROUGH WHICH UNIVERSITIES, INDUSTRY, AND GOVERNMENT AGENCIES CAN COMMUNICATE.

THEY SHOULD REPORT PERIODICALLY ON PROGRESS IN THEIR FIELDS, BE AN INFORMATION RESOURCE AVAILABLE TO PUBLIC POLICY MAKERS, AND PROVIDE CONTINUING ASSESSMENTS OF WHAT OUR COMPETITORS IN OTHER COUNTRIES ARE DOING.

THE NSF SPONSORED ENGINEERING RESEARCH CENTERS HAVE BEEN A SUCCESSFUL WAY TO BRING THE UNIVERSITIES, INDUSTRY, AND GOVERNMENT MORE CLOSELY TOGETHER. THE IDEA IS NOW BEING EXTENDED TO SCIENCE IN THE NEW SCIENCE AND TECHNOLOGY CENTERS, ONE OR MORE OF WHICH COULD DEAL WITH SUPERCONDUCTIVITY. I CAN NOT OVER EMPHASIZE, HOWEVER, THE IMPORTANCE THAT THESE CENTERS BE ESTABLISHED BY MERIT-REVIEWED PROPOSALS TO MAINTAIN THE BEST POSSIBLE RESEARCH EFFORT.

BUT IT WOULD BE A SERIOUS MISTAKE TO BELIEVE THAT THE KEY TO SUCCESS WILL BE A NATIONAL PROGRAM THAT IS CENTRALLY CONCEIVED AND DIRECTED. IT IS OUR BELIEF THAT THERE IS A WIDESPREAD PERCEPTION THAT IS HOW THINGS ARE DONE IN JAPAN, BUT THERE IS MUCH EXAGGERATION ABOUT THE JAPANESE GOVERNMENT'S COORDINATING ROLE.

EVEN IF THIS PERCEPTION WERE CORRECT, IT WOULD BE THE WRONG WAY FOR US TO GO. OUR STRENGTH IS IN THE INDIVIDUAL INITIATIVE OF OUR SCIENTISTS, OUR ENGINEERS, OUR ENTREPRENEURS, AND OUR INDUSTRIALISTS. WE SHOULD DO EVERYTHING WE CAN TO HELP SUCH PEOPLE IN DIFFERENT INSTITUTIONS COOPERATE AND WORK TOGETHER, BUT WE SHOULD DEPEND ON THEM TO MAKE THE CRITICAL DECISIONS ABOUT WHERE TO PUT THEIR RESOURCES FOR THE BEST RETURN.

CONCLUSION

MR. CHAIRMAN, IN MANY WAYS THE RECENT ADVANCES IN SUPERCONDUCTIVITY SHOW HOW WELL THE AMERICAN SCIENTIFIC AND ENGINEERING RESEARCH SYSTEM IS WORKING.

O STEADY, BROAD SUPPORT ACROSS ALL IMPORTANT FIELDS ENSURES THAT WE WILL BE PREPARED WHEN A MAJOR BREAKTHROUGH OCCURS.

O EFFORTS TO ENCOURAGE MULTI-DISCIPLINARY GROUP RESEARCH EFFORTS ARE INCREASING. IN SUPERCONDUCTIVITY WE HAVE PHYSICISTS, CERAMICISTS, METALLURGISTS, CHEMISTS, AND MANY OTHERS WORKING TOGETHER.

O EFFORTS TO BRING INSTITUTIONS CLOSER TOGETHER ARE ALSO INCREASING. UNIVERSITIES, INDUSTRIES, AND NATIONAL LABORATORIES HAVE MUCH TO LEARN FROM EACH OTHER. THEY NEED TO LEARN TO WORK TOGETHER AND COOPERATE MORE CLOSELY.

O THE ROLES OF NSF, OTHER AGENCIES, OF INDUSTRY AND OF THE UNIVERSITIES ARE RELATIVELY CLEAR AND WELL UNDERSTOOD. ALL ARE IMPORTANT, AND ALL MUST BE RESPECTED IF THE BASIC RESEARCH, THE EDUCATION OF NEW SCIENTISTS AND ENGINEERS, AND THE DEVELOPMENT OF NEW COMMERCIAL PRODUCTS IS TO PROCEED AT AN OPTIMUM PACE.

THOSE ARE THE POSITIVE POINTS. BUT I WILL CLOSE WITH A WORD OF WARNING:

TURNING BASIC RESEARCH IN SUPERCONDUCTIVITY INTO PRACTICAL TECHNOLOGIES WILL BE A LONG AND DIFFICULT PROCESS. SOLVING THE MANY PROBLEMS ALONG THE WAY WILL TAKE BOTH PATIENCE AND COMMITMENT.

JAPAN HAS SHOWN IN OTHER AREAS THAT SUCH PATIENCE AND COMMITMENT CAN PRODUCE SPECTACULAR RESULTS.

OUR ECONOMIC AND INDUSTRIAL CULTURE FINDS IT DIFFICULT TO DO THE SAME. BUT IF WE DO NOT SUSTAIN THE EFFORT FOR THE TIME NECESSARY -- AND THAT TIME MUST BE MEASURED IN YEARS, NOT MONTHS -- THEN OTHERS WILL REAP THE BENEFITS OF THE INSIGHTS OUR LABORATORIES HAVE PRODUCED.

THANK YOU.

Senator FORD. Thank you. Dr. Kerber?

STATEMENT OF DR. RONALD L. KERBER, DEPUTY UNDER SECRETARY OF DEFENSE, RESEARCH AND ADVANCED TECHNOLOGY, DEPARTMENT OF DEFENSE

Dr. KERBER. Thank you, Mr. Chairman. I appreciate the opportunity to discuss the Department of Defense's research program into high temperature superconducting applications, and superconductors.

I do have a brief statement that I would like to give you for the record.

Senator FORD. You may proceed. Whatever statement you have will be included in the record as if given. A highlight would be fine.

Dr. KERBER. Thank you.

Foremost among the military requirements is the need for equipment that will give us an edge over a range of combat situations and environments.

Fundamental to acquiring this equipment is the availability of technical options that would give us a basis for superior systems.

It is the goal of the science and technology program in the Department of Defense to provide those future options.

The program covers technologies of importance to national security, and employs the facilities and skills of industry, universities, national laboratories, and defense laboratories to achieve the department's technical goals.

Technology gives defense, for its systems, the options that include capability, survivability of our systems, and affordability of our systems.

Efforts such as the VHSIC program, the very high speed integrated circuits program, and our software programs, have as a prime consideration the goal of, not can or can't we do something, but can we do it in an affordable manner.

Another important consideration of our technology program is, do we have the potential for an increasingly competitive strategy relative to the Soviet Union?

Among technologies important to a competitive strategy are things such as Stealth, counter-Stealth, computer software, materials, lasers, communications, sensors, and artificial intelligence.

All of these technologies are the kinds of things we look for in defense. And superconductivity and semiconductors offer us some options that in fact we need to exploit for defense systems.

In February, 1987, the Defense Science Board task force concluded that while our dependency on foreign sources is modest today for semiconductors, semiconductor manufacturing trends indicate that we will become increasingly dependent on foreign sources if some action is not taken.

The superiority of U.S. defense systems of all types relies strongly upon superior electronics, a force multiplier which not only enhances the performance of weapons system, but also maximizes their efficiency in their application.

Electronics technology is the foundation upon which much of our defense strategy and capabilities are built.

In response to the task force report, we have spent the last several months developing detailed plans that address specific DOD needs.

Our planning efforts including working with industry as they plan SEMATECH.

The SEMATECH proposal has generated concern within the administration, as well as within Congress, over what Federal actions versus what industrial actions are appropriate to resolve this problem.

The Department of Defense has always had access to the leading semiconductor technology in the world. The decline of our lead in this technology is a new experience for us.

Much of what needs to be done to improve semiconductor competitiveness rests in the private sector. Government cannot legislate competitive success.

The Department of Defense, however, has a real interest in the strong success of the semiconductor industry. It is simply not feasible for us to consider stockpiling semiconductors, or duplicating the innovation that exists in the industrial base.

We must rely on a competitive U.S. industry. For these reasons, we are developing a plan of action that calls for research and development options including manufacturing, research and development, packaging, assembly, test of military semiconductors, and a fabrication capability; all of this in coordination with SEMATECH.

It is our intent to work closely with industry so that these efforts will satisfy our national security and foreign dependency concerns, as well as help the private semiconductor industry with the state of art technology needed to remain competitive.

In fiscal 1987 the Department spent over $350 million in semiconductor technology, and in 1988, we anticipate over $500 million in research and development in that area.

Much of this technology has spinoff potential in the domestic sector. During the planning process in the semiconductor research area we have worked with other Federal agencies, OSTP and other agencies.

The second topic I wish to discuss is our high temperature superconducting technology program. On June 10th, 1987, testifying before the House Committee on Science, Space, and Technology, I detailed the rich history of the Department of Defense's contributions to science and technology in superconductivity.

I will not repeat that history today. But I do wish to point out that the activity extended well over 40 years, and accounts in large measure for the very strong position of the United States in this area today.

On balance, the DOD emphasis has been on small scale applications, specifically in the area of superconducting sensors, electronics, and we have achieved records in speed, accuracy and sensitivity.

We have also had notable success in large scale superconductivity applications such as electric ship drive and pulse power sources.

We expect significant benefits for military applications through our interactions with the superconductivity research centers called for in the President's superconductivity initiative.

The initiative calls for the Department of Defense to spend nearly $150 million on superconductivity research and development over the next three years.

The Department will systematically define the engineering parameters for high temperature superconducting materials, develop the required processing and manufacturing capabilities, and accomplish the necessary engineering and operational prototype testing to prove the use of superconductor-based military systems.

To guide this activity we have had a joint planning effort that has been carried out with the services, DARPA, SDI, and other agencies.

The Department has increased its Fiscal 1987 funding for superconductivity research and development from $5 million to $23 million.

For the superconductivity program, as well as the semiconductor programs, the Department will seek to explore projects and areas that provide the greatest potential for improving the Nation's security posture.

In conclusion, I would like to thank the committee for the opportunity to discuss our programs, both in superconductivity and in semiconductor research and manufacturing technology.

I also appreciate the opportunity the Committee has given us to comment on S. 1480 and the Department is reviewing the bill and expects to provide comments in the timeframe that you have provided.

Thank you.

[The prepared statement of Dr. Kerber follows:]

HOLD UNTIL
RELEASED BY
THE COMMITTEE

THE DEPARTMENT OF DEFENSE
STATEMENT ON
SEMICONDUCTOR DEPENDENCY AND SUPERCONDUCTIVITY

BY

DR. RONALD L. KERBER
DEPUTY UNDER SECRETARY OF DEFENSE
FOR RESEARCH AND ADVANCED TECHNOLOGY

TO

THE SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
OF THE
COMMITTEE ON ENERGY AND NATURAL RESOURCES

UNITED STATES SENATE
100th CONGRESS, FIRST SESSION

SEPTEMBER 1987

Mr. Chairman and Members of the Committee:

I am Ronald L. Kerber, Deputy Under Secretary of Defense for Research and Advanced Technology. I appreciate the opportunity to appear before the Committee today to discuss Department of Defense activities in high-temperature superconducting applications and semiconductor manufacturing technology. I am responsible for the Defense Science and Technology program which encompasses those particular areas.

A strong military capability is a combination of national resolve, industrial capability, morale, leadership, training and other ingredients. However, foremost among military requirements is the need for superior equipment that can provide an "edge" over a range of combat situations and environments. Fundamental to acquiring this equipment is the availability of technical options that can be the basis for developing increasingly superior systems. It is the task of the Science and Technology program to provide those future options.

The Science and Technology program meets this challenge by using both the public and private sectors to produce the technological know-how required for the development of superior equipment. The program covers technologies of importance to national security and employs the facilities and skills of industry, universities, National laboratories and Defense laboratories to achieve the Department's technical goals.

In the selection of projects to be undertaken in the Science and Technology Program, we are influenced heavily by the need for increased performance derived from the technologies pursued. However, there are other important considerations. Affordability is one of those considerations. Efforts such as the Very High Speed Integrated Circuits (VHSIC), the Microwave/Millimeter Wave Monolithic Integrated Circuits (MIMIC) and Software programs all have as a prime consideration not that it can or cannot be done but can it be done in an affordable manner.

Another important consideration is the exploitation of those technologies that have a high potential for use in an increasingly competitive strategy vis-a-vis the Soviet Union. Among the technologies of particular importance are stealth, counter-stealth, computers, software, materials, lasers, communications, sensors and artificial intelligence. A competitive strategy approach to building those capabilities will allow us to meet national security objectives with increasing efficiency and effectiveness.

There are, of course, other considerations such as foreign dependence, unusual high payoff opportunities and new increased threats . Today I plan to discuss foreign semiconductor dependence and high temperature superconducting applications, a problem and an opportunity.

In a February 1987 report, the Defense Science Board Task Force on Semiconductor Dependency concluded that, while our dependency on foreign sources is modest today, semiconductor manufacturing trends indicate that we will become dependent on foreign sources soon if actions are not taken. The most significant finding of the Task Force was that U.S. semiconductor technology leadership is rapidly eroding and that this has serious implications for the national security. In their words, "U.S. Defense strategy relies upon technologically superior weapons to overcome the numerical advantage of our adversaries. Our capability to field technologically superior weapons may soon, be dangerously diminished. The superiority of U.S. defense systems of all types is directly dependent upon superior electronics, a force multiplier which not only enhances the performance of the weapon system themselves, but also maximizes the efficiency of their application through sophisticated intelligence and command and control systems. Electronics technology is therefore the foundation upon which much of our defense strategy and capabilities are built. The United States has historically been the technological leader in electronics. However, superiority in the application of innovation no longer exists and the relative stature of our technology base in this area is steadily deteriorating."

The Task Force made specific recommendations to the Department which they felt would redress the effects of current trends on U.S. military capability. These included: 1) support the establishment of a Semiconductor Manufacturing Technology Institute, 2) establish centers of excellence in semiconductor science and engineering, 3) increases emphasis in DoD technology base programs and 4) provide discretionary R&D credits to defense semiconductor research, development and manufacturing.

In response to the Task Force report we have spent the past several months developing detailed plans that address specific DoD needs. This effort has not been easy. It involves consideration of the political, economic, and technical issues of not only the semiconductor industry but also of the so-called "upstream" and "downstream" industries (those that supply materials and equipment to the semiconductor industry and those that consume the products of the semiconductor industry, respectively). Additionally, our planning efforts have been complicated in that the industry is currently proposing the establishment of SEMATECH and is asking the government to fund 50 percent of the cost of the consortium. This amounts to approximately $100 million per year for the next five years. This proposal has generated concern within the Administration as well as in the Congress over what federal actions versus what industrial actions are appropriate to resolve the problem.

The Department of Defense has always had access to leading semiconductor technology and this has contributed significantly to the strength of our military forces. The decline of our lead in this technology is a new experience for us. Much of what needs to be done to improve U.S. semiconductor competitiveness rests in the private sector. Productivity is the responsibility of management and labor, as are the product and market strategies that address global markets. Government cannot legislate competitive success.

The Department of Defense, however, has a real interest in the competitive success of the industry. We cannot, as some have suggested, build our own arsenals to make the world class semiconductors we need. It is simply not feasible for us to consider stockpiling semiconductors or duplicating the innovation that exists in the industrial base or competing for the high level of technical personnel needed to develop the leading technology for our weapon systems. We must rely on a competitive U.S. industry that produces the best semiconductors in the world.

For these reasons we are developing a plan of action that calls for research and development. Options being considered include: 1) manufacturing research and development in coordination with SEMATECH, 2) packaging, assembly and test of military semiconductors, 3) developing a minifabrication capability, 4) increase electron device R&D in the DoD technology base and 5) establish centers of excellence. These efforts constitute a balanced program in semiconductors that will satisfy military requirements. It is our intent to work closely with the industry on this initiative so that these efforts will satisfy our national security and foreign dependency concerns as well as help provide the semiconductor industry with the state-of-the-art technology needed to remain competitive.

In FY 87 the DoD will spend over $350 million and in FY 88 over $500 million on semiconductor related research and development. Much of this work has spin-off potential to the domestic sector. For example, our Very High Speed Integrated Circuits program has developed a hardware descriptive language, electron-beam and x-ray lithography machines, testers, etc. and has made a variety of technical advances in semiconductor processing, all of which can be used by the industry for manufacturing commercial state-of-the-art semiconductors. Our management approach has been to fund industry to perform this research and development so that the capability to produce the products we need will be developed and resident in industry. Where specific R&D efforts are of mutual benefit to the DoD and to industry we have encouraged cost and sharing arrangements. The SEMATECH concept fits well with our general management approach. Over the next few months we will be working closely with SEMATECH to develop the technical road maps that define areas of mutual benefit and specify the technology transfer mechanisms that will allow our weapon systems to directly benefit from this research and development.

During our planning process we have coordinated with a variety of other federal departments and agencies. Our technical people have participated in the SEMATECH workshops and in the National Academy of Sciences National Laboratory workshops. Currently, in the semiconductor area, we are providing funding to the Brookhaven National Laboratory for x-ray synchrotron radiation, to the Lawrence Livermore National Laboratory for laser pantography, and to the Sandia National Laboratory for radiation hard semiconductors. We plan to continue to work with DoE's National Laboratories in the future to assure that the best talent and capabilities in the country are brought to bear on this most important problem.

The second topic I wish to discuss is our high temperature superconducting technology program. We are pleased with the progress in this area and look forward to the promises it affords for solving difficult military problems. On June 10, 1987, testifying before the House Committee on Science, Space, and Technology, I detailed the rich history of Department of Defense contributions to the science and technology of superconductivity. I'll not repeat that history today, but I do wish to point out that the activity, extending over a period of forty years, accounts in large measure for the very strong current position of the United States in the very exciting technology of superconductivity. The Department of Energy , with a history of superconductivity research and development nearly as long, can also claim a good measure of the credit for our current strong position.

Over the years the Department of Energy and the Department of Defense have enjoyed a productive, synergistic, and mutually beneficial relationship in superconductivity research and development as well as in other fields of science and technology. On balance, Department of Defense emphasis has been on small-scale applications, specifically superconducting sensors and electronics, which have set new records for sensitivity, speed, and efficiency. However, we have also achieved notable successes in large-scale superconductivity applications such as electric ship drive and pulsed power sources.

In the new era of high temperature superconductivity we look forward to continuing beneficial and synergistic relationships with the Department of Energy. In addition, we expect significant benefits to accrue to military applications through our interactions with the Superconductivity Research Centers called for in the President's Superconductivity Initiative.

As you are doubtless aware, the initiative calls as well for Department of Defense to spend nearly $150 million on superconductivity research and development over the next three years. The Department of Defense will systematically "define the engineering parameters for high temperature superconducting materials, develop the required processing and manufacturing capabilities and accomplish the necessary development, engineering , and operational prototype testing" of superconductor-based military systems. Emphasis will be on "sensor, electronic, and superconducting magnet-based military applications."

To guide this activity a joint planning effort has been carried out by Army, Navy, Air Force, National Security Agency, Defense Advanced Research Projects Agency, and the Strategic Defense Initiative Organization. From this activity it is apparent that a very long term and intensive commitment will be required if the military potential of high temperature superconductivity is to be realized. As demonstration of commitment to this goal the Department of Defense has increased FY 1987 funding for superconductivity research and development from its originally planned level of $5 million to $23 million. We view this as only a down payment in a very challenging, demanding, and long-term endeavor.

With the superconductivity program as well as the semiconductor program, the Department will seek to explore those projects and areas that provide the greatest potential for improving the nation's security posture. In addition, we will foster to the best of our ability spinoffs to the private sector in order to maximize benefits from our R&D investment. In accomplishing this work, we plan to seek out the best talent available in the industrial, university, national laboratory and DoD sectors. In addition, we plan to provide special management procedures in executing these programs to assure that national goals are met in a timely and effective manner.

In conclusion, I would like to thank the committee for the opportunity to discuss our semiconductor and superconductivity programs because of the importance we attach to them. Also, I appreciate the opportunity the Committee has given us to comment on S.1480. The Department is currently reviewing the bill and expects to provide comments within the time frame you requested.

Thank you and I will be pleased to respond to questions you may have.

Senator Ford. Thank you very much, Doctor. I think many of the questions I had have been answered in the statements given by each of the witnesses.

Dr. Decker, let me ask you a question, if I may. You seem to support the goals of this legislation but you do not support the legislation.

Are you opposed to taking the action that the legislation requires?

Dr. Decker. I think we have already taken a number of actions that are the major thrust of this bill in terms of moving ahead with laboratories, helping to form and working with cosortia of industries.

We do have some difficulties with some specific provisions of the bill, as I indicated. But the general goals of the bill we certainly support.

Senator Ford. If you are intending to do the things that the bill requires, and you've already started doing some of the things that the bill requires, it would be very helpful if the agency could lend its support, in my opinion, to what we are trying to do here, and have a cooperative spirit between the Congress and the Department.

Be that as it may, you are a good soldier, and I understand that, and OMB is God.

Thank you very much, Pete. Now, Dr. Decker, have the patent changes negatively impacted the integrated conductor system in Defense, and Naval reactor labs. Could you explain that in English to me?

I have a little hard time with some of the larger words.

Dr. Decker. I will try to.

As you know, the Department of Energy has responsibility for the whole nuclear weapons program from R&D through production. The success of that program to some extent depends on a very free flow of information among contractors.

The concern is, that by introducing the possibility of gains from commercial spinoff of some of that technology, the free flow of information within that system will be inhibited; that one contractor would tend to keep information from other contractors who are part of that integrated contractor system.

Senator Domenici. Mr. Chairman, might I ask a clarifying question?

Senator Ford. Yes, sir.

Senator Domenici. Let me just see if I am right.

The Department of Defense in various areas of activities has things going on that have just the same kind of concern as you have expressed about those two programs, do they not?

Dr. Decker. I am sure that is true.

Senator Domenici. Are you aware that the rules on patents and royalties, with reference to the Department of Defense, are considerably different than yours?

They have a time certain to classify, and then they are finished. They seem to think that protects so-called secrets, and military privacy within their domain.

Do you think your secrets are more important to be protected from the private sector than theirs?

Dr. Decker. Well, certainly secrets of nuclear weapons technology are very important to the country. And I think that they have been pretty well protected by the contractors in the past.

The proposal we are introducing includes a new factor in which there is potential gain to the laboratory, to the inventor involved with nuclear weapons related research and development, from commercialization of the technology. So if I were a contractor in that business, I am not sure I would want to be put in a potential conflict situation in which I would sometimes be called upon to decide on the classified nature of material that might offer a very large commercial gain from which I could profit.

Senator Domenici. Thank you, Mr. Chairman.

Senator Ford. How does NASA handle all of their patent matters? They have regional offices where you can come to the office there, and they will look up anything they have for you.

Is that any different than what we are talking about here? Doesn't NASA have an open book, almost, on what they have discovered in new research and development? Don't they kind of put that out?

Dr. Decker. I think they do. I am not that familiar with NASA.

Senator Ford. I know they do.

Dr. Decker. It is the same for the Department in programs that are not supported by Defense Programs or Naval Reactors, such as the Offices of Energy Research and Fossil Energy, and other parts of the Department.

Senator Ford. Let me ask you this. Should the technology transfer mechanisms developed in this legislation be specific to the three technologies?

Or should these mechanisms apply generally to all work at the labs?

Dr. Decker. I would say that there are a lot of provisions in here that apply to a broad range of technologies, and I think as Senator Domenici mentioned earlier that maybe they should be considered in a broader context.

Senator Ford. Dr. Graham, have you reviewed the proposals with respect to the intellectual property patents, copyrights, and so forth in the Domenici legislation?

Dr. Graham. Not in great legal detail, Mr. Chairman, but in the general sense of them, yes.

Senator Ford. Can you give me your general opinion, then, your analysis of this aspect of the legislation?

Dr. Graham. My impression is that it would allow the government to assign rights from the laboratories by license and by other means, first, to contracting operations under the laboratory, and then to private industry.

In general we support that approach.

Senator Ford. Does the fact that some of this technology has defense significance, does that make a difference? And if it does, how?

Dr. Graham. Well, of course, the conditions of national security, and the limitations of information transfer regarding national security would apply here, just as they have in the past, and to the extent that the DOE or other programs have national security implications and require classification, that would have to be respected in the future, just as it has been in the past.

Senator **Ford**. Well, Dr. Graham, should we cooperate with other countries in developing these technologies?

That is, do we need to cooperate to get rapid progress for every one? Or do we need to emphasize U.S. development without foreign participation?

Dr. **Graham**. Mr. Chairman, I believe in basic scientific research, we have an inherently international activity, and one where scientists make a point of comparing discoveries and comparing theories with people, not only in this country, but around the world.

And again, to the extent that it does not get into potentially militarily sensitive areas, the basic scientific research is much strengthened by the fact that it is an international undertaking, and one based on free and open publication.

I would add that when I say "open" I mean open in both directions; and that means that other countries which are advanced in their technology, are highly industrialized and dependent upon the progress of technology for their own economy, have a strong obligation themselves to invest in basic scientific research, and to contribute that to the international pool of knowledge in science.

The situation in my view is quite different in applied industrial research, where the research is directed at specific commercial, or in some cases, military applications, and where it is very important to the competitive advantage of a company to pursue that within its own environment, and not to share it with its competitors.

And I think it appropriate that our companies be allowed to do that, and to make such alliances or such partnerships as they see commercially beneficial; but not to have the government intrude to dictate that they have transferred commercially important information to other countries and the government, not through such inadvertent mechanisms as the Freedom of Information Act, transferring commercially sensitive information itself.

So it depends on whether you are talking about the basic research or the applied industrial research.

I believe the government has a very strong role in the open basic research, and I believe the government does far better to let industry support the applied industrial research.

Senator **Ford**. Well, do you think commercial application of superconductivity is nonclassified?

Dr. **Graham**. Certainly to date, the applications I am aware of have been unclassified.

Senator **Ford**. Then why did you object to the foreigners meeting at the White House meeting on superconductivity recently, I believe it was in July? And you closed the door to any foreign attendance at that meeting, and you were attributed as the individual making that decision.

Dr. **Graham**. Yes, sir, the decision was one that I made, and the decision was not quite as stated. But rather, it was that the invitees to that particular conference, which was a conference on the potential commercial applications of high temperature superconductivity was to be domestic corporations and U.S. companies and institutions.

Because it was basically a meeting on domestic competitive issues, and we wanted to get, if you will, the home team together to discuss with them the challenges before us as a country, and before them, as U.S. industry, and lay it to them on the line.

Commercial foreign companies were not invited, and foreign country representatives were not invited, because the meeting was not directed to them.

We were not talking to them, and it did not seem appropriate that they be part of the attendance. There was nothing classified about the meeting, and as you know, the press was certainly there.

Senator **Ford**. Well, I visited the lab near Chicago recently on superconductors, Fermi, and I asked how the superconductor was financed.

And they had a board up there on who was investing the money in research and development. And I would say there were at least five, six, maybe seven foreign entities that were involved in the whole works.

They put millions and millions of dollars in, particularly Japan. And that was our first big breakthrough. Everybody was beating drums, ringing bells, and getting up before daylight on that one.

And for you to object to others coming to that meeting and getting the home team together, it looks like the home team is dependent on a lot of money from foreign entities as it relates to that breakthrough.

Dr. **Graham**. This is a good example of the difference between basic research in science, Mr. Chairman, and the specific commercial applications in which the U.S. must compete in a very, very tough, high technology world market.

The Superconducting Super Collider is a basic research project. It is of such a size and expense that it is unlikely in my view that two such scientific research instruments will be built anywhere in the world.

Nevertheless, we certainly think it is appropriate that the research done on that machine be research that involves a broad base of international cooperation.

And therefore we feel it appropriate that the countries that will eventually participate in that basic research also participate in the construction of the scientific instrument necessary to carry out that research.

And therefore, we encourage international participation in the SSC. But that is not a competitive, commercial, industrial project. That is the development and construction of a large scientific instrument for basic research purposes.

Senator **Ford**. I'm going to quit, Pete, but it is beyond me when we say this is the greatest thing that has happened in a long time, and this country is far ahead of any other country as it pertains to the superconductor, and yet, they take all that and go home and accelerate it, and we sit here and look at it.

The first thing you know, they are way ahead of us and they are gaining on us from the information they took from us.

It seems at that point you might want to keep it with us, and when you have already commercialized it, let it go.

I am just a country boy here trying to figure out what is going on. And you smart boys know what to do. But I still have to vote whether you get the money or not, and I am beginning to wonder a little bit about some of the procedures.

Dr. **Graham**. Mr. Chairman, we are no smarter than the wisdom in the statement you just made.

It is the concern that the U.S. industry has become complacent in the acceptance and development and implementation of new advanced technologies, and that the U.S. industry cannot afford to continue to be complacent in that, but has to move very rapidly and very hard to be competitive.

That was the message that we wanted to give to U.S. industry in high temperature commercial superconductivity.

Senator **Ford**. I hope the government will give some leadership in awakening industry in this country.

Dr. **Graham**. That conference was certainly a step that we took to that very purpose. I hope it was successful.

Senator **Domenici**. Thank you very much, Mr. Chairman.

Let me first say to you, Dr. Nicholson and Dr. Graham, it is very helpful to me, and I commend you, to see that somehow or other, in a very short period of time, from the date the President delivered his State of the Union address, and suggested a national effort with reference to science centers, that you, Dr. Graham, with the Secretary of Energy, and hopefully the President, have decided that the executive order was very short-sighted, when it comes to centers of excellence that require the pulling together of resources.

Dr. Nicholson, you told this committee a minute ago that you are very hopeful that if we are able to fund some of the new centers of excellence, that you could not believe that a few of them would not be in superconducting.

And if I heard you right, that you could hardly believe that some national laboratories would not be involved in the best proposals which would be funded.

Now the reason I am making this point now is that the Department of Energy and the national laboratories were not even involved in the executive order that was going to move us ahead in the development of applied technology and research.

The National Science Foundation was going to be charged with it, and it specifically mentioned that they were going to work with academia and industry.

Dr. Graham, you were aware of that. That is what was there, and the labs were left out. If we have done nothing else in the last five or six months, we have changed that.

Your director is testifying before the Congress repeatedly that he does not intend to bypass the excellence of the national laboratories and the creation of the centers of excellence.

I only tell you that because I do not believe that it is enough, with reference to nine treasures like the national labs, to have all of you people sit up here and say, we agree with some goals, they are marvellous, and we have got everything worked out; do not worry about it.

I just do not believe it. I believe they are going to be left sitting behind again, either because of the reluctance on the part of the Department of Energy to take some risk and be bold and use them.

And I do not think they have to be overused, and I do not think we have to sacrifice anything.

Let me just give you a couple of examples, Dr. Decker. I do not have any current information, but the best I can get is a GAO report, December of 1986, with reference to your department and waivers.

It takes up to 50 months, with an average of 14, according to GAO, at the end of 1986, to get a waiver. And also, when questioned as to the reason for the delay, the GAO report says, and I quote: It is a low priority within the Department.

Now, the performance would indicate that is true, that it is a low priority.

The abundance of patent attorneys within the Department of Energy seems to me to be some indication that we are still busy at the work of running that Department as if it were the same kind of Department as when its principal and sole responsibility in this Nation was the development of everything nuclear, which was before your day and before mine.

I think we have kept every patent lawyer since those days, and they are still over there. As a matter of fact, with the Chairman's permission, I will submit a question for you to answer for the Committee.

How many patent lawyers does the Department of Energy have on its payroll? And give us a four or five year trend line; are they going up or going down.

I would greatly appreciate that.

Dr. DECKER. I will supply that.

[The information follows:]

	1980	1981	1982	1983	1984	1985	1986	1987
Headquarters	18	17	13	9	7	7	9	7
Field	37	35	35	33	31	29	29	28
Total	55	52	48	42	38	36	38	35

Includes patent attorneys and patent agents.

Senator DOMENICI. Now let me tell you my experience, Dr. Graham and Dr. Decker.

I had 150 of America's CEOs in front of me in an audience with a smattering of public sector people and academia. They were from all over. It was your conference, Dr. Graham.

I asked, how many of you private sector people have had any kind of relationship with one or more of the national laboratories. I did not ask about patents or royalties; just a relationship, the exchange of knowledge, that you all tell us is the beginning of technology transfer.

I think about 11 people put up their hand that they had some.

How many have received any license or patent from any of the labs? Two. And one wanted to explain it a little bit. He was not sure that he was leaving the wrong impression. It was not quite a forthright straight patent relationship.

I frankly do not think the nine labs are being used when that kind of situation exists. And I have not questioned them across the board yet, but it was a pretty good smattering.

I also would comment to the committee that when the vice president of General Electric, Dr. Schmidt, has said publicly that he does not believe it is worthwhile to work with the national laboratories on matters of research because the process is too cumbersome, bulky, and he cannot get anything out of it. Given this type of industrial perception, I do not think it serves the purpose that you all, both of you, have described today and the goal that you say you have.

And something is amiss. Now, Mr. Chairman, when somebody, one of the witnesses, talked about a system of patenting at the government-owned government-operated lab seemed to be working well—was it you, Dr. Nicholson? Who said that? Perhaps Dr. Graham.

Senator **Ford**. They are all denying it.

Senator **Domenici**. Well, you could admit it, because it is probably working fairly well.

But I just want to suggest to you that if it is, all we are trying to do in this legislation is to make it apply to the labs that are not run by the government, but are nonprofit organizations, such as the one that operates Sandia Laboratories. We tried, in the comments to you today, to say, we are not going to let them make a profit. They have to put all their royalties back into the institution.

But right off, when you have a significant number of the national labs that are not government owned or government operated, that is, university controlled or the like, you have two sets of rules, is that not right?

One set of present rules applies to them, and another set applies to those that are run by the private sector under the Bayh-Dole act.

Why should we not apply it to all of them?

Dr. **Decker**. We are in the process of granting past patent waivers to the for-profit run laboratories. That is held up right now in regulatory review.

But we expect that to happen fairly soon.

Senator **Domenici**. What will that mean?

Dr. **Decker**. That will mean that the for-profit contractors operating our laboratories such as Oak Ridge will get patent rights for those inventions that have come out of any program, I guess, except Defense Programs and Naval reactors.

Senator **Domenici**. Let me ask you, why do you have to do that with the executive order that the President signed, as part of that same address that I am telling you that he gave. He also said, I am issuing an executive order with reference to patents.

Do you assume it does not apply to the DOE?

Dr. **Decker**. I believe that Executive Order applied to the government owned, government operated laboratories, but not the government owned, contractor operated laboratories.

Senator **Domenici**. So if you are going through the waiver process that you just described, you are saying that is made necessary because the executive order does not cover part of your activities that are at Sandia, Oak Ridge, and the like?

Is that what I hear you saying? I cannot believe that.

Dr. **Decker**. Well, I am not sure why exactly we have to go through that. I will get you the answer for the record.

Senator **Domenici**. I would appreciate it.

[The information follows:]

The disposition of rights to inventions made under DOE contracts is governed by law. DOE contractors who are nonprofit organizations or small businesses generally may elect ownership of inventions they make pursuant to the provisions of the Bayh-Dole law, 35 U.S.C. 200. The only exceptions to this rule (35 U.S.C. 202) are for exceptional circumstances, for international agreements, and for DOE's weapons-related and naval nuclear propulsion programs at DOE weapons laboratories. The latter exception is based on national security reasons in view of the unique role given to these laboratories. Section 152 of the Atomic Energy Act of 1954 and Section 9 of the Federal Nonnuclear Research and Development Act of 1974 provide that title to inventions vest with the Government, unless these rights are waived, for all other contractors. The only authority DOE has for giving enforceable and valid ownership to for-profit contractors or to inventions excepted under 35 U.S.C. 202 above is through the waiver provisions. The Executive Order (No. 12591) does not, of course, alter this statutory patent policy applicable to DOE and contains the specific provision "to the extent permitted by law."

Dr. **Graham**. Senator, might I add a brief comment, that in my experience of just under a year in OSTP, I have found DOE anything but reluctant to take initiative in this area of technical transfer.

And while certainly we come from a long tradition of secrecy in the nuclear weapons program, nevertheless, in my experience, DOE has been in the lead among the government agencies in seeking new ways to facilitate technical transfer.

They were the particular agency sponsor of the conference on commercial applications. On high temperature superconductivity, which you were so kind as to preside in this session.

They were at the lead in establishing centers for research on high temperature superconductivity.

They have reprogrammed funds very early for work on this. And in general, I found them certainly willing to take initiative, and where necessary, to take risks, to facilitate this transfer.

I certainly agree with you that we have far too little traffic between industry and the Federal laboratories today, and there is certainly much more we in government can do.

But I think the conference, and your role in it in particular, also helped tell industry that they have a responsibility; you as industry has a responsibility to get out and find out what is going on in the laboratories, and to make use of that.

The fact that Argonne was able to establish this Argonne University of Chicago research corporation is a strong indication that there is initiative in the laboratories and in the Department.

And I hope that is matched in the near term by initiative in U.S. industry.

Senator **Domenici**. Dr. Graham and Dr. Decker, let me tell you my version of why that will not work, this kind of cajoling and encouraging.

Because the experience has been too poor in the past—let me just give you an example. MIT, with one-tenth of the DOE's budget in basic science, had exactly the same amount of technology transfer measurable in licenses and royalties, as all the DOE labs combined.

And I am not talking about the nuclear work in labs. I am talking about comparable R&D work in the two institutions, one sitting up there, and nine spread out across America.

I think the reason industry is not running to the knowledge base is because the experience of the past of getting anything out of it is too poor. Although we are going to keep working on this, and push industry to look at the labs.

I think you need some legislation that assures them of a result if they make a deal, and then have the history for awhile, so they know it will work.

And then you will get a change of attitude. That is one of the reasons why I think we have to put some of these arrangements into legislation, just to be honest with you, because I do not think the attitude is going to change so long as it is based on just asking them to do it.

They are going to go elsewhere in my opinion.

I have a number of additional questions. But we also have a very long afternoon, Mr. Chairman, and a number of witnesses.

I would like to submit some of the questions to the panel, and I want to close by thanking in particular you Dr. Graham for beginning to push in these areas.

I think we have got a long way to go, and I hope we do not get ourselves straitjacketed into any assumptions as to what the labs' role is. We should not rely on the past, and make the assumption that the labs should not be involved in anything but basic research. We cannot assume that there is no room for enabling technology or arrangements with the private sector, just because the labs have a mission which they do well.

I think all those things are true. But unless and until we maximize their utility, I just do not think we will reach our goal.

Mr. Chairman, I thank you again for the hearings.

Senator **Ford**. Thank you, Senator Domenici.

Senator Bingaman, and then we will get to the Congressmen after this panel.

Senator **Bingaman**. Thank you very much, Mr. Chairman.

Let me ask Dr. Kerber if I could a question. Secretary Herrington has designated Los Alamos as a lead lab on technology transfer in superconductivity research, as I understand it, the research and development results, the results of that R&D.

In light of that DOE role that has been imposed on that laboratory, do you believe that it makes sense for DOD to also involve the Federal laboratories in the research program that DOD pursues in superconductivity?

I know that DOD does significant research through the Federal laboratories in various areas, the Department of Energy laboratories.

Do you believe it is appropriate for DOD to pursue some of the superconductivity research through those laboratories as well?

Dr. **Kerber**. I believe we are already doing that. As you know, the program is concentrated around ceramics technology, and Los Alamos is strong in that technology.

And they are doing work, I believe, in that area. I understand that we have at least two national labs under contract from DARPA right now, about—we have 11 different projects.

And we anticipate, as I indicated to you, that we are going to be putting more resources in the out-years into this area, and so those national labs which are strong in those areas, not only Los Alamos but Livermore and Sandia, we anticipate, will be contributors to that program.

Senator **Bingaman**. Let me also ask you, Dr. Kerber, on the issue of the level of funding, if you were to pursue a program that was not limited by the budget, but was rather limited by the technology in this area of superconductivity research, can you give us an estimate as to the level of funding that you think would be appropriate for fiscal year 1988 and 1989?

I understand that you have got $50 million per year proposed by the President in his 11-point program. Do you believe that is adequate? Or would a higher level of funding allow us to accomplish some of this research more quickly?

Dr. **Kerber**. Let me answer that with a caveat.

As you know, every technology in a sense is a level of effort. When we have a level of effort that we apply toward semiconductors and toward superconductivity, toward materials, toward sensors and seekers, and many, many areas.

When we develop the budget, we make the tradeoffs that are, we feel, appropriate, that the Department can support in those various technology areas.

It is clear that in any given technology if we get more funds, we are likely to make more progress. Our problem as we see it is that if we have certain technologies that are earmarked, and the Defense budget does not go up, our role to defend the country has not changed, but now we have another restriction on how we can spend our resources.

And so we try to make a very careful analysis of what we can afford in various technical option areas to have a level of effort that we think is consistent with what we can do to exploit that technology.

So, of course, in any given technology, the more resources, the more we can anticipate progress. But we have to look at the total mission of not only our tech base, but the Department of Defense.

Senator **Bingaman**. Dr. Decker, let me ask on this technology transfer issue, my understanding is, that at the present time, the problem that has occurred is that requests from the contracting laboratories, the national laboratories, to DOE for waivers are being held up, as Senator Domenici said, for inordinately long periods; or that has been the history of it, at least in the views of some.

We have a provision that we put in the defense authorization bill which is presently being considered on the floor of the Senate, which would provide that requests for waivers from the laboratories to DOE would have to be denied in 180 days or else they would automatically go through.

Now as I understand Senator Domenici's proposal in this legislation—and that would be generic for any research going on—I understand his proposal would limit that, would take the same basic idea, but take it to 90 days rather than to 180 days.

I guess I am confused at this point because of your earlier statement that you are presently in the process of concluding regulations within DOE which would make the need for any kind of a waiver moot, at any rate, because you are just going to say that as to all DOE laboratories, they are automatically going to own those patents, and DOE is out of the loop.

Is that what you said?

Dr. **Decker**. No, not quite. There is one exception, and that is still with Defense Program-funded work and work funded by Naval Reactors.

Senator **Bingaman**. The exception is which?

Dr. **Decker**. Work funded by the Defense Programs portion of DOE and also Naval Reactors, our two main defense-related R&D efforts.

In that case a contractor would still have to come to the Department for a waiver on a case-by-case basis.

Senator **Bingaman**. So that you would, as I understand your overall budget is about $12 billion, and $8 billion of that is defense-related, so that you are saying that for two-thirds of your budget, the process that you have had will remain in effect under your new regulation?

Dr. DECKER. I guess that is probably right. I would like to make one comment however. I think the Department has been slow in granting some waivers, but I think the situation is improving. I saw a list from one of our attorneys the other day that indicated that a significant number of workers had been granted within a month's time. We have some that go on for fairly long periods of time. But I think you have to look at each case to see where the problem lies, in terms of necessitating a long period of time. Sometimes I know that there has been a lot of time on the contractor's end. So that is something that really has to be looked at carefully.

Senator BINGAMAN. If we went ahead with legislation of the type we are talking about here, so as to handle that other two-thirds of your budget, if the 180-provision or the 90-day provision were realistic?

Dr. DECKER. Since I am not in that end of the business, it is hard for me to answer. But I will get you an answer for the record.

[The information follows:]

DOE prefers not to have rigid time limits on waiver processing in view of the complex considerations which may be applicable in some situations and the potentially significant negative effect on national security. If there is a time limit, it should not be less than 6 months. The provisions of the 1986 Defense Authorization Law provided for waiver decisions to be made in a reasonable time, "usually within 6 months." This appears to require action by DOE within 6 months, unless there is some special situation which would warrant additional time. National security concerns should not be compromised based on a rigid time table. There is no operational data during this last year which indicates that this approach has not worked. Significant progress has been made in the last year by reducing the waiver delays noted in the hearing from an average of 14 months to less than 10 months. The continuation of this provision therefore is preferred by DOE.

Senator **Bingaman**. Okay, I think that would be good, and it would good to get it fairly soon if it is going to be relevant to the DOD provision.

Let me just ask Dr. Graham on the council on superconductivity for American competitiveness, you refer to that in your testimony, I just wondered how far you say the recent formation of an independent council on superconductivity for American competitiveness. Could you elaborate a little bit on who is on the council and how it functions and what responsibility or authority it would have?

Dr. **Graham**. Senator, that has been in formation through the summer, and I can give you a more accurate status if I answer you in writing, which I will do immediately.

Senator **Bingaman**. Do you know if the membership is complete on that council, and do you know if the national laboratories, which are the main focus of Senator Domenici's legislation, are represented on that council?

Dr. **Graham**. No, I do not know if it is complete yet, and I am not aware of the full representation, so I will respond to you.

Senator **Bingaman**. That is all I have, Mr. Chairman.

Senator **Ford**. Thank you, gentlemen.

Senator **Domenici**. Mr. Chairman, could I follow up on one item that Senator Bingaman raised?

Senator **Ford**. Yes, I would be glad to. We have a Congressman here who is getting awfully nervous. He has 25 years of experience in this field, and he can speak their language. He can pronounce their names.

Senator **Domenici**. I will be very, very quick.

Senator Bingaman, let me just address the issue that you were raising with respect to how much of the laboratories of the DOE budget is covered by the waiver requirement.

I hope, when I was stating that there is a distinction between a government owned, government operated, and a private sector operated, using that as an example, with the panel, that I was not understood to mean that because Los Alamos is technically run by the University of California, that it is exempt from the waiver process.

Because as a matter of fact it is not. What the Department of Energy had done, it has taken the Senator Bayh-Dole bill, and if you read it, it seems like the government owned should be exempt from the waiver process.

But there are two exceptions to the Bayh-Dole, one of which is weapons related and national security.

And so what you all have done, by putting the whole lab off limits to anything but the waiver process, is taken three more; so that makes six instead of three that are basically—and they are very large in terms of their impact on your budget.

You have six that are operating under the waiver process, whereas some, looking quickly at Bayh-Dole, may think there are only three.

That is the current situation as I understand it. What you are attempting to grant some waivers on, is that correct, some broad waivers on?

Dr. **Decker**. No, I think it is a little different. Right now we are in the process of modifying the contracts for Los Alamos, Livermore and Berkeley that are operated by the University of California, so that they will get patent rights, automatically, to any discoveries that come from research supported by my office, with the exception that is in Bayh-Dole for Defense Programs supported work and Naval Reactor supported work.

Those they still have to get waivers on.

Senator **Domenici**. Can you report to us in writing as to what the current situation is, and if you are changing it under the contract with the University of California, how you propose to change it?

Dr. **Decker**. Sure.

Senator **Domenici**. Because it is in the process of being negotiated, is it not?

Dr. **Decker**. That is correct. It should be signed any day now.

[The information follows:]

Negotiations with the University of California have been completed and the contracts have been signed by both parties. The University may now elect title to all inventions outside the excepted areas previously noted. This includes all superconductivity, human genome mapping and semiconductor inventions funded outside the weapons programs. In the excepted areas the University will continue its current practice of seeking waivers on a case-by-case basis.

Senator **Domenici**. And the University of California is rather upset about the lack of transferability of royalties—I mean of patents. And that is a part of the new contract, it will extend that a little bit and broaden it.

Dr. **Decker**. I am not aware that they are upset. I think we have reached agreement with them.

Senator **Domenici**. I am not talking about the current agreement. I am talking about the way it was operating before.

Dr. **Decker**. Oh, that may be.

Senator **Domenici**. Thank you very much.

Senator **Ford**. Gentlemen, you have agreed to answer several of the questions in writing, and I hope you will do that as expeditiously as possible.

There may be other questions that will come in writing to you, and hope you will respond in like manner.

We thank you for your attendance today, your statements, and above all, your patience.

Now, Congressman, we are looking forward to you, and I am going to take a shot at your name, Hochbrueckner.

I imagine that with your background and experience, you would lend a great deal to this. And we look forward to your statement, and I apologize for keeping you so long.

STATEMENT OF HON. GEORGE J. HOCHBRUECKNER, A U.S. REPRESENTATIVE FROM THE STATE OF NEW YORK

Mr. **Hochbrueckner**. Thank you very much, Mr. Chairman. I appreciate the courtesy you have extended to me today.

And as you point out, I do come from a background of——

Senator **Ford**. Why do you not just wait a minute? All of the department heads are taking their employees with them, so the crowd is getting a little bit short.

When they get through testifying, they all go back to the agency, or stop by for three.

Now, Congressman, I apologize for the disruption.

Mr. **Hochbrueckner**. No problem.

As you point out, I do come from a background of 25 years of involvement in aerospace electrical engineering, and consequently, I thought it would be appropriate for me to come here today to express my strong support as a member of the House and a member of the Armed Services Committee in the House, with regard to the goals of S. 1480.

Certainly if one looks at page two of the bill, under findings and purposes, items four and five point out that a new national initiative is needed to increase the flow of energy related technology from these laboratories to the private sector. And five, the goal of the new initiative should be to link the nation's capabilities for generating scientific and energy related technological innovations with capabilities for commercial activities.

Clearly, that comes down to new transfer of technology, which is absolutely essential to us as we move toward a world economy.

Clearly we have seen more basic manufacturing shifting from our nation to others, and consequently, our future job opportunities lie in the area of high technology.

And that is why it is absolutely imperative that we see to it that the ideas of the thinkers are transferred as quickly as possible to the doers, in order for our people in manufacturing to produce marketable items for the commercial marketplace.

So that is why I am pleased to be here to support this legislation, and to indicate that I certainly will be promoting this bill, and its approach, in the House.

As you know, Congressman Lujan has introduced the equivalent bill, H.R. 3006, and it will be before three committees that will have jurisdiction, including Armed Services.

And I would like to point out that there is probably no better example of why this kind of legislation is needed than to look for example in the area of computer chip technology.

As you know, the DSB in February of this year came out with a report, the Defense Science Board, indicating that the United States had lost the leadership in computer chip technology; that the Japanese, who essentially were not in the game a dozen years ago, exported more computer chips than we did last year.

And of course in light of the fact that we are losing much of our basic manufacturing capability, and that our future lies in high technology job categories, it is imperative that we take back that leadership. And I am pleased to say that there is a program that will help us do that. And it is this kind of legislation that would encourage this kind of a program and other programs, in order to enable us to take back the leadership in various high technology fields.

Certainly this program is referred to as X-ray topography. And I think the Defense Science Board rightly pointed out that the three best opportunities that the United States has for taking back the lead in computer chip technology are laser lithography, direct electron beam etching, and also, X-ray lithography.

And as it turns out, we have a lab, the Brookhaven National Lab in New York, which really is the leader in the field of X-ray lithography techniques and synchrotron.

And it is the basic synchrotron, which is a device that it would take two of these rooms to contain, which produces the kind of X-rays that will allow us to get into the next generation of computer chip.

Certainly the VHSIC program that was referred to before will allow us to get down to the 1¼ micron element size of computer chip. X-ray lithography offers the promise of chips that are a quarter of a micron.

So clearly, this is a direction that we must go. And one of the reasons I am here today also is to appeal to my colleagues in this house to recognize that in the House, in the budget right now, we have allocated $40 million for the purpose of developing X-ray lithography.

It is actually a two-pronged approach. One, of course, is to develop the manufacturing techniques associated with producing computer chips that are 25 times smaller than what are available on the marketplace today.

And of course recognizing that in computers, smaller is faster, and faster is better; because that is where the cutting edge of technology is.

As you know, electrons move at close to the speed of light. And it is obvious that if you can reduce the distance between elements, you have a faster computer; and faster is better.

So it is important that we fund this program, and I am pleased to say that on the House side, at present we do have $40 million built into the budget to, one, develop the manufacturing techniques associated with X-ray lithography; and second, to take this huge synchrotron, which as I said takes two of these rooms to contain, and to produce a more portable version, using cryogenics and superconductivity in terms of our magnet construction, in order to produce the kind of throughput and manufacturing numbers that we need in order to compete effectively with the Japanese.

So there is a program that is very important to this Nation. And in my formal presentation, which has been submitted to the subcommittee, you will find some details as to exactly where the money is.

There is $20 million under DOD, and $20 million under DOE. It is absolutely essential from my point of view that money be forthcoming this year to kick off this six-year multimillion dollar program which ultimately offers the best opportunity for the United States to take back computer chip technology leadership from the Japanese.

So X-ray lithography can happen. But it is happening because people like myself are promoting it, and we are trying to come up with the money to do it.

We need legislation similar, if not identical, to S. 1480 and H.R. 3006, in order to see to it that this transfer happens more on its own from our national labs and our universities to the marketplace through our product manufacturers.

It should not be necessary that everytime something important like this comes along, we have to go find the money and make it happen.

It is better if, in fact, the administration sees to it that the technology transfer happens. And then I think, Senator, you bill is the direction to go in order to stimulate that kind of transfer.

That is the name of the game. That is the future of our Nation in terms of the high paying manufacturing jobs. It is absolutely essential that we go in this direction.

So I commend you for the research that you obviously have done to put this bill forward. And I just want you to know, you have a champion in the other House, certainly in addition to Congressman Lujan and others who I know are promoting it.

So I thank you for your time. And I would be happy to answer any questions. And I appreciate your courtesy.

[The prepared statement of Mr. Hochbrueckner follows:]

TESTIMONY OF CONGRESSMAN GEORGE J. HOCHBRUECKNER
Before the
SENATE ENERGY AND NATURAL RESOURCES COMMITTEE
ENERGY RESEARCH AND DEVELOPMENT SUBCOMMITTEE
September 15, 1987

EXECUTIVE SUMMARY

With a 25 year background in Aerospace-Electrical Engineering:

* I strongly support the purpose and goals of S.1480. THE MOST IMPORTANT GOAL IS TECHNOLOGY TRANSFER TO THE COMMERCIAL MARKETPLACE

* I WILL PROMOTE AND SPONSOR SIMILAR LEGISLATION IN THE HOUSE OF REPRESENTATIVES

* I SUGGEST IMMEDIATE SENATE BUDGET ACTION ON "X-RAY" LITHOGRAPHY, WHICH IS A PERFECT EXAMPLE OF THE GOALS OF S.1480 AND IS NEEDED NOW IN ORDER TO DEVELOP THE NEXT GENERATION OF COMPUTER CHIPS AND RECAPTURE THE LEADERSHIP IN COMPUTER CHIP TECHNOLOGY. I APPEAL TO THE SENATE TO JOIN THE HOUSE IN BUDGETING $40 MILLION THIS YEAR TO SUPPORT THIS TWO-PRONGED PROGRAM: THE DEVELOPMENT OF
1) "X-RAY" LITHOGRAPHY MANUFACTURING TECHNIQUES AND
2) THE "PORTABLE SYNCHROTRON" REQUIRED FOR THIS PROCESS.

TESTIMONY OF CONGRESSMAN GEORGE J. HOCHBRUECKNER
Before the
SENATE ENERGY AND NATURAL RESOURCES COMMITTEE
ENERGY RESEARCH AND DEVELOPMENT SUBCOMMITTEE
September 15, 1987

Mr. Chairman, members of the Subcommittee, I'm here to personally lend my strong support for the purpose and goals of S.1480. A new initiative is needed to increase the flow of technology from our laboratories and universities to the private sector and the commercial marketplace.

It is that flow of ideas from the "thinkers" to the "doers" which is essential to maintaining our overall high technology leadership and is the best hope to reduce the hemorrhaging of high technology manufacturing jobs from the U.S.

Please be assured that I will be working with my colleagues in the House to assure the introduction and passage of similar legislation.

There was a recent time when it was possible to dismiss this nation's eroding position as the world leader in high technology by indulging in convenient rationalizations. The demise of our position as the world's leading producer of semiconducter computer chips is particularly illustrative of the problem. "Foreign competitors can mass produce less expensive microchips because of cheaper labor costs," such reasoning generally went, "but our domestically produced chips are more advanced technically."

We must face the painful reality that such reasoning is no longer accurate. For those of us who have examined the situation with growing concern, it is no longer possible to try and explain away our nation's decline in this area of high technology.

I approach this topic with particular interest, as a result of my professional background of 25 years in the field of electrical engineering. With that in mind, I will focus my comments today on the field of semiconductor technology, as well as the compatible applications of high-temperature superconducting technology. It is for this reason that I am interested in Senator Domenici's bill, S.1480, which promotes semiconductor technology under Title III, the "Semiconductor Technology Manufacturing Excellence Initiative", and furthers superconducting advances under Title I, which would establish national centers for joint government-industry work in this area.

I mentioned earlier that it is no longer correct to say that domestically produced computer chips are more advanced technically than those being developed by the Japanese. This is not something I have determined on my own; that assertion was contained in a special report released last February by the Defense Science Board. That analysis of defense semiconductor dependency found the quality of American microchip technology to be "steadily deteriorating" in comparison with the Japanese.

The same report concluded that the military's increasing dependence on foreign sources of supply for state of the art computer chips is an unacceptable situation. The danger we face comes on two fronts. No nation can be secure when it depends on foreign sources of supply for the vital components of its defensive systems. Nor can that nation be secure economically, when it imports many times more in foreign products than it exports. Suffice it to say that this a position of extreme peril for the United States.

However, ours is not a future without promise. There have been technical breakthroughs in which this nation has a solid lead, and which need only be exploited to their full potential for us to recapture the international lead in high-tech products. X-Ray lithography is just such an exciting breakthrough in the field of semiconducter technology.

X-Ray lithography uses the high intensity X-Rays produced by a synchrotron to produce computer chips with circuit features of only .25 microns in width. This compares favorably with current technology, which can produce features that are 1.25 microns in width. By reducing both the length and width of a chip by a factor of five, X-Ray lithography will produce chips that are 25 times smaller than the current generation of computer chips.

Because electrons move at a constant rate of speed, approaching the speed of light, making chips smaller also makes them faster. It is an axiom of our technological world that in computers, faster is better. X-Ray lithography is a technical breakthrough which will certainly be exploited by someone.

That exploitation should be by American industry. The United States currently holds an impressive lead over the rest of the world in synchrotron design and engineering, primarily as a result of research programs being conducted at Brookhaven National Laboratory, where much of the preliminary work in the development of X-Ray lithography currently is taking place. The next step is the development of small, commercially applicable synchrotron equipment for use by U.S. industry.

Meanwhile, progress in superconductivity goes along hand-in-hand. For instance, a key to the development of smaller synchrotrons is the use of superconducting magnets. High temperature superconducting materials, a technology which is also being pioneered at BNL, will enable the development of commercially useful synchrotrons, and thus, advance X-Ray lithography.

Of course, the Japanese and West Germans are not far behind. It should come as no surprise to those who have witnessed the economic developments of recent years that the Japanese and West Germans have already embarked on active research programs into development of this promising technology. For this nation to develop X-Ray lithography into a commercially viable process will require the investment of about $400 million over the next 6 years. A preliminary investment, sufficient to allow plans for a more complete development program to be drawn up, has already been made.

However, it is important that we recognize, through programs similar to that envisioned under Article III of this bill, that we cannot afford to surrender any of the technical lead we still enjoy. For that reason, we must be prepared to intensify, rather than diffuse, efforts such as the ongoing work into commercial development of X-Ray lithography being conducted at Brookhaven National Laboratory and the University of Wisconsin. American industry, already interested in the exciting possibilities of X-ray lithography, should have every opportunity to take the lead. I believe we have that opportunity and applaud those efforts to advance the coordination of U.S. research and industrial ingenuity.

"X-RAY" LITHOGRAPHY NEEDS $40 MILLION IN FUNDING IN THIS YEAR'S BUDGET. Presently, the House has included $40 million total in two areas. $20 million was passed in the Department of Defense Authorization bill, HR 1748, page 158. It stated that, "The importance of semi-conductor technology to Department of Defense weapons and support systems was recognized by the committee nearly ten years ago... The Department of Defense can accomplish still another advance in technology by applying X-ray lithography techniques to micro-electronics."

$20 million was also passed in the House Energy and Water Development Appropriation bill, HR2700, page 82, to "initiate a technology program in x-ray lithography aimed at restoring U.S. leadership in the manufacture of high density computer chips. Key elements of the program will focus on research and development aimed at 0.25 micron x-ray lithography manufacturing."

WE MUST ACT NOW TO SUPPORT "X-RAY" LITHOGRAPHY. LET ME NOTE

THE CONCLUSIONS OF A RECENT ARTICLE IN NEW SCIENTIST, 13 AUGUST 1987 (attached), which STATES:

> "All this activity indicates that Japan is bidding to dominate the microchip markets of the future. It now seems likely that by the middle of the next decade, Japan will have more synchrotrons in operation than any other country, including the U.S."

The Japanese are coming on strong. In order to compete effectively we must begin the "X-Ray" lithography program in this year's budget and the total of $40 million is absolutely essential to move toward our goal.

Japanese bureaucrats clash over plans for superchips

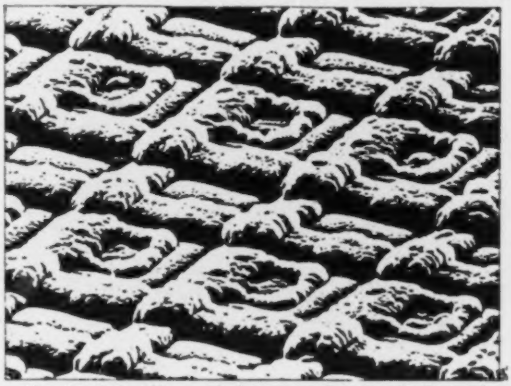
Bob Johnstone, Tokyo

AMBITIOUS plans in Japan to build expensive machines for fabricating the next generation of finer silicon chips have created a deep rift within the government.

The country's Science and Technology Agency has angered the Ministry of Education, Science and Culture by proposing to spend more than £500 million on machines called synchrotrons. They generate fine beams of radiation that technicians can use to etch tiny features on chips. The features may be less than one millionth of a metre in diameter, making the chip far more versatile than existing ones with cruder features.

The ministry accuses the agency of having invaded its territory. Officials at the ministry are complaining that the agency announced its proposals for backing the research without consulting it first.

The feud is serious, because most of Japan's specialists in synchrotron research are the ministry's own employees. Without the backing of the education ministry, it is unlikely that the agency's plans will succeed. A further complication is that the ministry has its own plans for synchrotron research.



Chips like this could become obsolete once synchrotrons make their mark

The science agency proposes building 17 synchrotrons. They include one big machine, several medium-sized ones and a number of small ones.

The largest one, several hundred metres in diameter, will absorb energies of between 6 and 8 gigaelectronvolts to produce fine X-rays. The agency estimates that it will cost about £250 million to build and that it will take seven to eight years to construct.

The agency says that it can afford such a large sum because it has cut back on research related to nuclear energy. Already, the government has allocated to it a preliminary budget of £400 000 for a feasibility study to assess the merits of the synchrotron, and it has asked the agency to select a site for the machine. The agency is expected to choose Nishi Harima near Osaka where the government is offering land at a substantial discount.

The ministry's rival plan is to modify Japan's largest existing synchrotron to meet industrial needs. The ministry operates a so-called Photon Factory at the National Laboratory for High-Energy Physics in Tsukuba. It operates at voltages of up to 2·5 gigalelectronvolts. The laboratory also houses a larger accumulator ring, with energies up to 6 gigaelectronvolts, that feeds TRISTAN, a huge particle collider that is used in physics research. It is this machine that the ministry wants to readapt.

But its proposal has several shortcomings. One is that the machine is not optimised to produce synchrotron radiation; its beams are not concentrated enough to meet the needs of solid-state physicists.

Moreover, the education ministry cannot afford to fund another big facility; it can barely afford to run the ones it already has. For example, the Photon Factory runs for less than 3000 hours a year. Rival machines in other countries run for up to 5000 hours a year. The facility is also desperately short of staff.

Japan's government has frozen the number of civil servants that it employs. This means that physicists at the Photon Factory must work up to 16 hours every day. Several times a month, they must work night shifts to operate the machine.

An extra burden for the facility's 80 or so physicists is that they must accommodate researchers from industry who work there. Last year, 194 industrial researchers booked in at Tsukuba. In addition, the laboratory is conducting joint research with 21 companies. They represent a broad spectrum of industry, from steel and oil companies to those from the chemicals and rubber industries.

Many of these companies devote their efforts to experiments that produce quick, detailed information about the atomic structure of materials. But the overriding goal of researchers from industry is to use the synchrotron machines to make the next-but-one generation of microchip memories.

Four companies—Nippon Telegraph & Telephone (NTT), NEC, Hitachi and, most recently, Fujitsu—have each committed £4 million for construction of a "beam line" (a channel through which synchrotron light is tapped for experimental purposes).

They hope to use synchrotrons to etch chips with lines of less than one quarter of a millionth of a metre in width.

Though synchrotrons are expensive, at least £10 million each, they can be hooked up to eight or more beam lines connected to wafer exposers. So they are well suited in theory to the mass production of chips.

The problem is that they are too big at present to fit on the factory floor. Chipmakers worldwide are, therefore, hoping to make smaller, more manageable synchrotrons.

In Europe, there are two contenders, COSY Microtec of West Germany (*New Scientist*, 7 May, p 24) and Oxford Instruments, which recently received an order from IBM for a compact synchrotron.

In Japan, a massive effort is under way. Much of it is government-sponsored. The focus of activity is the Ministry of International Trade and Industry's Electrochemical Laboratory in Tsukuba.

Last February, in collaboration with Sumitomo Electric Industries of Osaka, the laboratory completed a prototype compact synchrotron that has a radius of 4·2 metres. Work on miniaturisation continues, with four companies taking part. The other three are Mitsubishi Electric, Toshiba, and the instrument maker, Shimadzu.

The government's Research and Development Corporation of Japan is giving Sumitomo Electric around £5 million over the next four years to develop a smaller synchrotron.

Another member of the same group of companies, Sumitomo Heavy Industries, is developing its own superconducting compact synchrotron independently. The company hopes to have it ready by 1989. Other companies said to be building their own synchrotrons secretly include Mitsubishi Electric, Hitachi, Toshiba and Furukawa Electric. The biggest and most guarded effort is that of NTT. It is building two synchrotrons at its Atsugi laboratories in Tokyo.

SORtec, a consortium of 13 manufacturers of chips and chip-making equipment, is also actively making smaller machines. The consortium was established to develop synchrotrons and peripheral technologies for microchip photolithography. It plans to build a synchrotron that operates at energies of up to 1 gigaelectronvolt at a facility adjacent to the Photon Factory in Tsukuba.

All this activity indicates that Japan is bidding to dominate the microchip markets of the future. It now seems likely that by the middle of the next decade, Japan will have more synchrotrons in operation than any other country, including the US. ☐

New Scientist, 13 August 1987

Senator **Ford**. Congressman, you are mighty nice. And I can tell from the way you are coming on there that you understand this field very well.

We enjoy your enthusiasm and look forward to working with you. I will have no questions.

Senator Domenici may have a question or two for you.

Senator **Domenici**. I really do not. I was going to thank you for your analysis and for your kind words.

We will try, Congressman, to take these six areas that I have described, where we have worked with different agencies to make modifications to the legislation.

We will try to get that language to all of you over there, the 5 percent limitation on that labs that we put in, and where the royalties would go in the for-profit labs going right back into the research, and the ultimate management decision remaining in DOE. Since they can cancel the arrangement if it is inconsistent with the purposes of the labs.

We will get you that very soon. Most of the objections other than the objection just to passing legislation are in those areas.

And we will attempt to get them soon.

I tend to agree with you that we have to put these relationships in place and insist that they occur on a regular basis by the operation of the marketplace between universities, the private sector and the laboratories.

I really do not believe they are going to happen unless there is legislation directing it and we get the obstacles out of the way and yet protect our security.

And I happen to think that can be done. That is why I am pursuing this course. And I thank you for your support.

Mr. **Hochbrueckner**. I hope we can look forward to your support for X-ray lithography.

Senator **Domenici**. We will do our very best.

Senator **Ford**. The next panel, panel two, will be Dr. Forsyth of Brookhaven National Lab; Dr. Schriesheim, Argonne National Lab; and Dr. Finnemore, Iowa State University; and Dr. Hecker, Director, Los Alamos National Lab.

If you gentlemen would come forward, we will try to take the same procedure we had with the other panel. I hope that you will hold your statements to roughly five minutes, and that we will then have sufficient time for some questions.

The committee is being reduced, so the questions therefore will be reduced, so we will go with Dr. Forsyth first, and then Dr. Schriesheim and then Dr. Finnemore and Dr. Hecker in that order.

If you would proceed, Dr. Forsyth?

STATEMENT OF DR. ERIC B. FORSYTH, CHAIRMAN, ACCELERATED DEVELOPMENT DEPARTMENT, BROOKHAVEN NATIONAL LABORATORY

Dr. **Forsyth**. Mr. Chairman, I am very honored to be here. I have submitted a more detailed testimony for the record.

Senator **Ford**. It will be included in the record.

Dr. **Forsyth**. I am lost without a vu-graph, I am afraid. So I will simply tell you what comes into my mind.

If you look at the illustrations in my testimony, it will be keyed to the remarks that I will make in the next few minutes.

I am specifically referring to Title I of the bill which is to set up centers for the development of the new high temperature superconductors.

My own experience over many years at Brookhaven is in the construction of the large magnets needed for superconducting particle accelerators, and also, transmission of electric power using superconducting cables.

And it is from this viewpoint, as an engineer and builder, that I will make some comments on the proposed bill.

New materials are definitely the basis for most engineering advancements. However, I think I should stress that we are in the very early days with the high TC materials.

The experience I have had at Brookhaven is that this is in fact a relatively inexpensive phase, and that the big money will come when applications are defined based on the first engineering data that comes from the research on the material.

Then I should stress that the actual form of superconductor needed is very dependent on the application itself, and there is an iterative interaction between the ultimate user and the developer-manufacturer of the superconductor to arrive at some kind of optimized design.

For example Brookhaven is building the R&D magnets for the superconducting super collider. The conductor consists of thousands and thousands of filaments of wire, all of them a good deal less than a thousandths of an inch thick.

We have also built the world's largest superconducting transmission line. In this case, the material was a flat tape, about a half an inch wide but extremely thin, and designed to operate at the highest temperature which we can achieve, which in fact is around about 8 Kelvin, using commercially available materials at the moment. So that itself is a good measure of how impressive the new materials are that operate at something like an order of magnitude higher in temperature than that, and promise, of course, tremendous improvements in the refrigeration and other engineering aspects of building superconducting systems.

However, what I am concerned about in the construction of the new centers is that from the language of the bill, there does not seem to be a direct user input. And so basically the bill is structured towards the materials science that precedes the user phase.

And I believe that this is something that should be addressed, that the user, whether it's a national lab or General Electric making a superconducting generator, in the end they will dictate what is needed.

The material scientist in the end has to provide what the user wants because they generally do not consider the economics, and the user does.

Another thing I will comment on is that when we develop these superconducting transmission lines at Brookhaven, we used niobium-tin, and yet it took us three years in the laboratory to get the form of niobium-tin needed for that particular application; and then it took a further five years before we could get long lengths of that material commercially available with the appropriate quality control from industry.

And I think the emphasis I would like to make here, and it has been mentioned by other witnesses today, that this is a field in which a sustained effort is needed.

We cannot be subject to fads of financial fluctuations caused by policy changes; that these things take many years to get to the marketplace.

The money for funding this kind of work tends to go up very rapidly when you get to a demonstration phase. And again, this is not particularly addressed in the bill, but it's something that I urgently ask you to look at.

In the submission I have made, I show a graph of our funding cycle at Brookhaven for the transmission line. The early days, the materials work are very inexpensive.

When you get to build large machines on the scale that the utilities are interested in, things do get expensive.

There is a relationship in my experience between the participation of private companies in R&D and the length of time it takes to develop applications.

We have not found at Brookhaven that the utilities industry is particularly interested at this stage in the application of superconductivity to power engineering, and the reason why is that it is a very mature industry, extraordinary standards of reliability are required for new equipment.

This means that to come under the market scene requires an immense amount of money. And when private companies look at the payback time, they will lose interest.

I think it is significant that the most successful commercial application of superconductivity is in magnetic resonance imaging. That is a medical procedure in which the devices themselves only cost a couple of million.

By utility standards, that is a very small amount of money. The payback time is rather quick. And I think there you can see commercial interest quite soon.

I think the moral on that is that if there is to be sustained development of equipment following the electric utility industry, other large users, such as transportation, of several years, probably a decade, it will require a significant government lead in order to do it.

I think that concludes my summary.

[The prepared statement of Dr. Forsyth follows:]

Written Testimony of

Eric B. Forsyth, Chairman
Accelerator Development Department
BROOKHAVEN NATIONAL LABORATORY

before the

UNITED STATES SENATE
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

September 15, 1987

Senator Johnston, members of the committee, and fellow attendees, I am very pleased and honored to present testimony in support of Bill S.1480. The aim of the Bill is laudable, but the actual implementation in an effective way will require considerable expertise on the part of the administrative agency and a thorough knowledge of the pitfalls and problems that have sometimes arisen in the past in attempting to integrate the R&D at National Laboratories, universities and private industry. Not that problems always arise; the High Energy Physics program and the National Synchrotron Light Source at Brookhaven are excellent examples of cooperation between the university user groups, industry and the Laboratory.

My involvement in the application of superconductivity covers the last seventeen years of my career at Brookhaven. The areas I am most familiar with are superconducting magnets for particle accelerators and superconducting cable for underground electric power transmission. In both these fields Brookhaven has achieved an international reputation. I will attempt to extrapolate the learning experience using niobium-based superconductors to the path that will be followed with the new high-transition temperature materials.

Without question, new materials are the underpinning for many significant engineering advances. However, the actual form of the conductor in any application is very specific to that application. Thus the ultimate performance of the device under development depends on close cooperation between project staff and the materials developer. This is an iterative process which must involve the commercial suppliers of the conductor at the earliest possible stage. The close relationship between the application and the materials development must be recognized in the demonstrated expertise required at the centers proposed in section 102 of the bill. An example is given in Fig. 1, which shows the laboratory phase required for the adaptation of the superconductor niobium-tin for alternating current power cables followed by the development in industry of methods of making long lengths with appropriate quality control. It can be seen the development period covered about eight years, bear in mind niobium-tin was a commercial, fairly well-understood material at the start of the development to use it for power cables. The conductor most commonly used for large accelerator magnets is niobium-titanium. Enormous strides were made in the 1960's and 70's to optimize this material for use in large, powerful magnets such as those found in particle accelerators and magnetic resonance imaging (MRI) systems. What is of interest is that improvements in the current density of this material are still being made and the very large magnets for the proposed Superconducting Super Collider (SSC) are designed to fully utilize the latest improvement; even with a well-tried conductor, materials development is a long-drawn out affair. An R&D magnet for the SSC is shown during fabrication at Brookhaven in Fig. 2. Another point to notice is that the improvements are being made in the current-carrying ability of the conductor. Although a high critical temperature material may permit many potential advantages in applications, it must be stressed that scores of important parameters are needed to characterize a superconductor - the critical temperature is certainly important but a high current-carrying ability is also crucial if the material is to have applications which are economically competitive with conventional conductors, or even with the present generation of superconductors. Another property which is essential to most applications is mechanical flexibility, this is achieved in the niobium-tin transmission cable conductor by bonding the superconductor to copper and stainless steel tape - the cable is formed by winding the conductor on a one-inch spiral, the completed cable can be wound on a ten-foot diameter reel, as shown in Fig. 3.

Perhaps now is a good time to clarify a common misconception about superconductors - one frequently reads in newspapers that they are "lossless". This is not the case - all superconductors (even the new ones) have to be deeply refrigerated and the power to run the refrigerator must properly be accounted for as a loss, i.e., energy dissipated without contributing to the actual function of the device. Although the higher operating temperature of the new materials promises to reduce the loss it is very likely that this potential saving will be translated into lower capital costs in actual applications. This is an old problem which in principle is quite independent of the superconductor itself. Over a hundred years ago the question was asked: how large should the conductors be to connect the hydroelectric generators at Niagara Falls to the city of Buffalo? The answer, provided by Lord Kelvin, is illustrated in Fig. 4. It can be seen the optimum losses are not zero, but those resulting from a conductor cross-section yielding a yearly cost of losses equal to the annual interest on the capital. Although the situation is much more complicated for a superconducting system the same principle holds: that some loss is desirable if capital costs can be reduced.

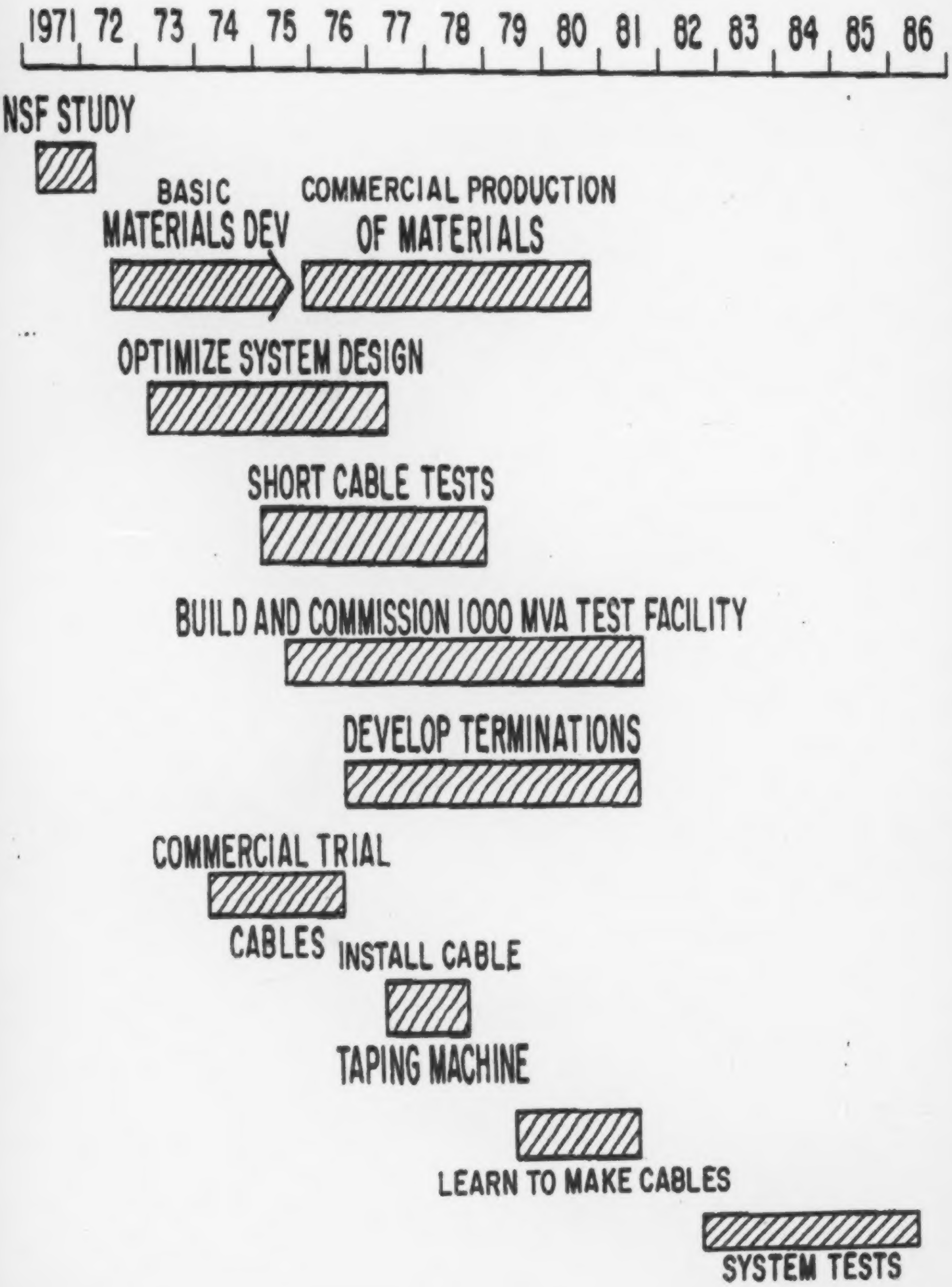
It is clear that the development of technically attractive, cost-effective applications of new superconducting materials will require solutions to the problems mentioned above and a host of other issues. There is certainly plenty of work for universities, the National Laboratories and industry. In organizing this effort there are some lessons to be learned from past experience. Here are a few observations:

Cost. The materials development phase of a project is relatively inexpensive compared to the cost of building prototypes and demonstrations. The funding profile for the Power Transmission Project at Brookhaven is shown in Fig. 5. The peaking between fiscal year 1976 and 1980 reflects the cost of building a prototype on a scale sufficiently large to be of interest to the electric utility companies. A view of the test site is shown in Fig. 6. The earlier phase, which was on a laboratory scale, was much less expensive, compare the profile with the time-line shown in Fig. 1. The drop in funding after 1980 reflects a shift in DOE R&D priorities. The next phase of development was examined, however. This would concentrate on transferring the expertise to industry and gearing up for the installation of a trial system in a utility network. Such a program would cost $50 to $100 million. This is because the equipment now used by utilities is very large and expensive and must demonstrate total reliability. New equipment must meet the same standards - this is an expensive process. The commercial pay-off for very large systems, such as electric power transmission, is so far down the road that industry is reluctant to share R&D costs. This situation is also true of superconducting generators and large energy storage systems. The short payback time and relatively low cost (about $1 million per unit) of MRI systems are probably major reasons why this application is one of the first commercial successes for the appreciation of superconductors.

Patents. The subject of patents and proprietary rights is a thorny one. Recent legislation has eased the problem of patent ownership of inventions developed with federal or shared funding, however the situation is far from satisfactory. If two or more companies work jointly on the same aspect of an R&D problem the question of an antitrust suit arises, this must be addressed more fully despite the language in the bill citing the National Cooperative Research Act of 1984.

The troika proposed to expedite the entry of new materials into the commercial sector is adequate to solve the technical and institutional problems. However the influence of the intended application in the actual form of the superconductor must be included in the required expertise of the proposed centers. Firm and inspired leadership will be required from the proposed Council for Research on Enabling Technology, in addition to sufficient and consistent funding.

ACTUAL SCHEDULE OF SUPERCONDUCTING CABLE DEVELOPMENT



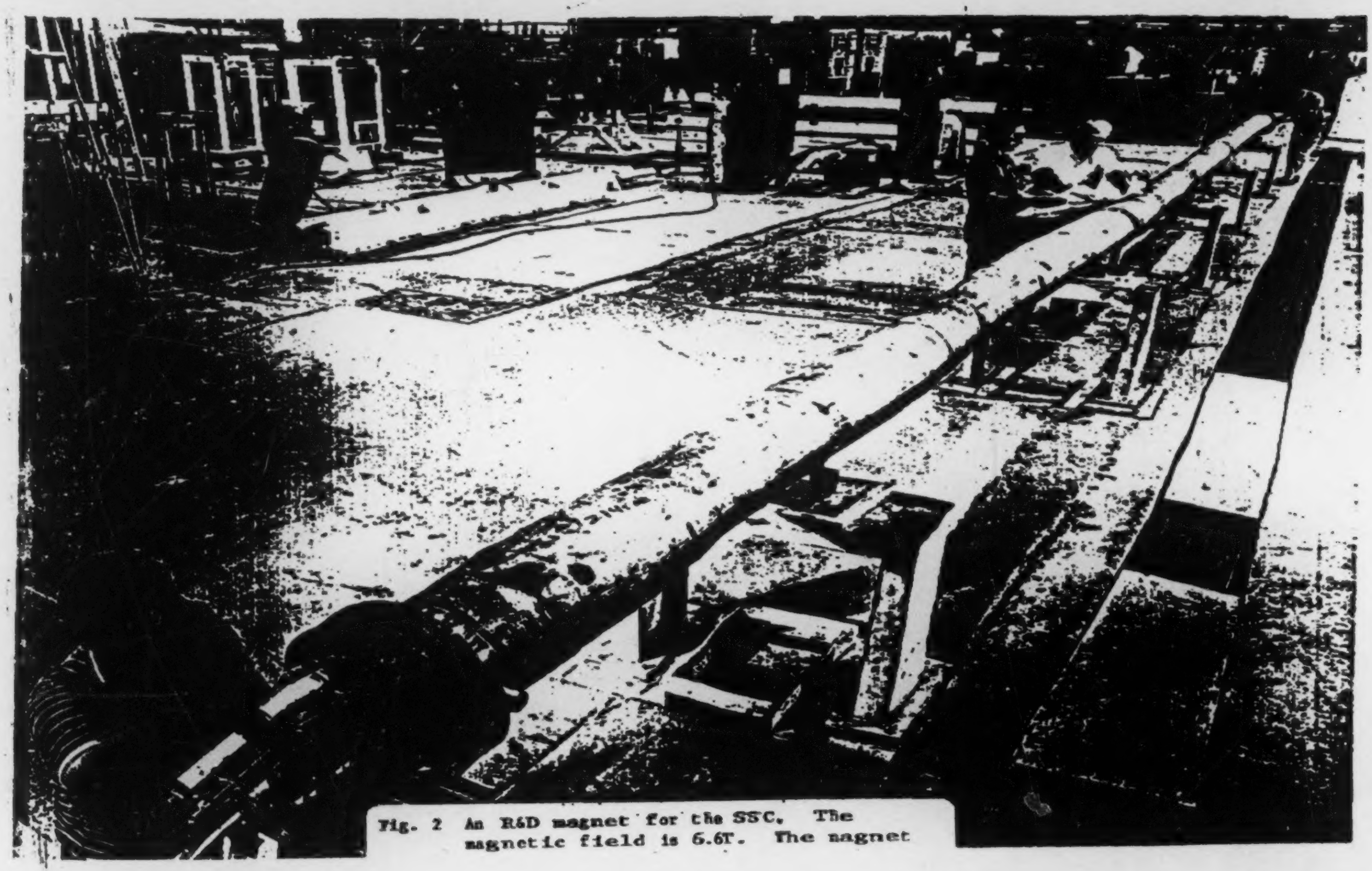


Fig. 2 An R&D magnet for the SSC. The magnetic field is 6.6T. The magnet

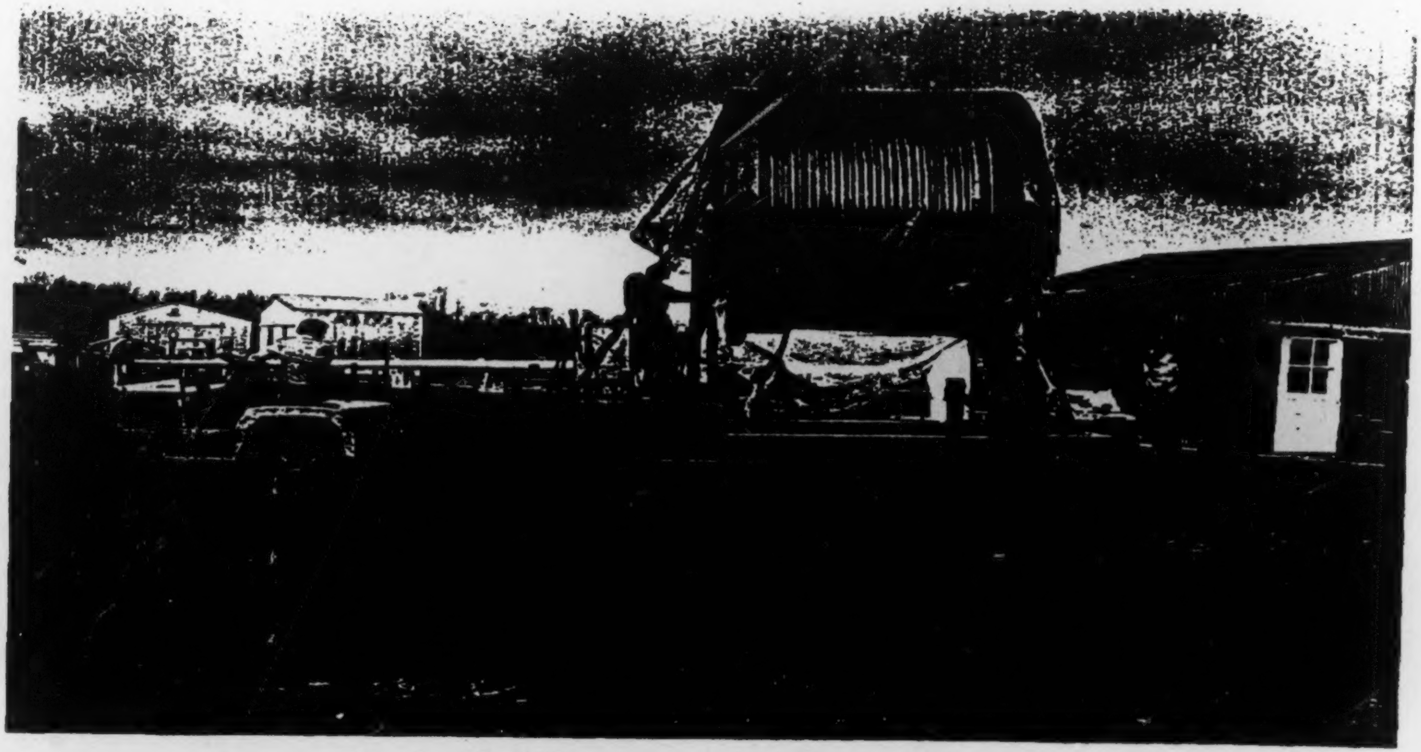
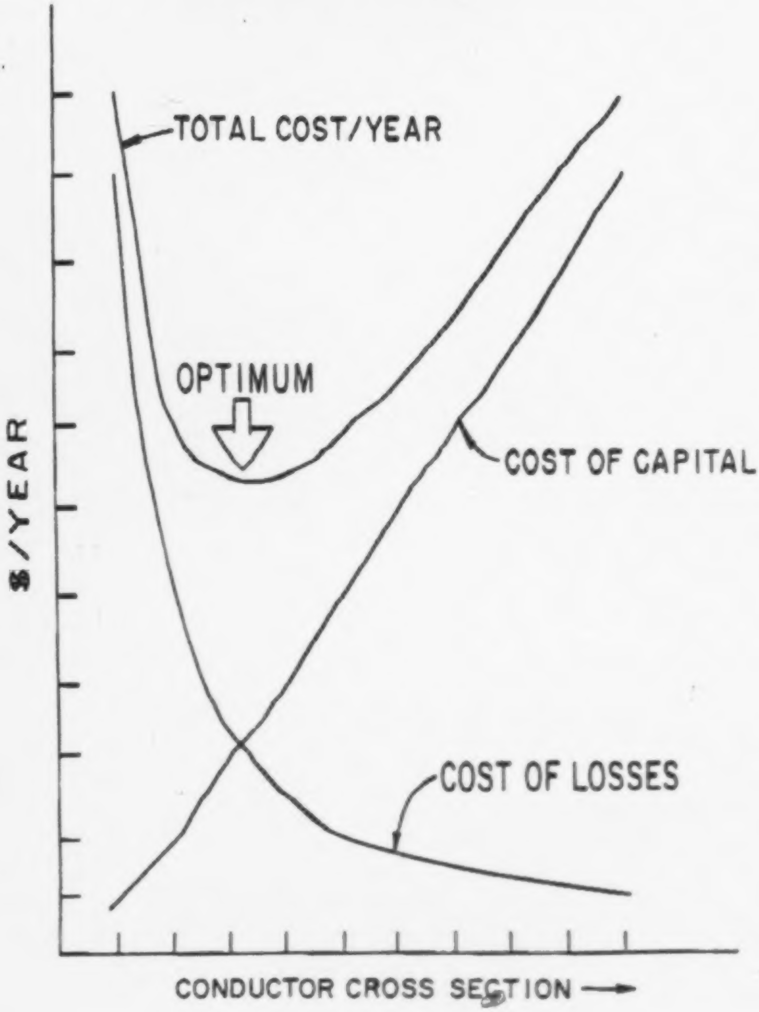
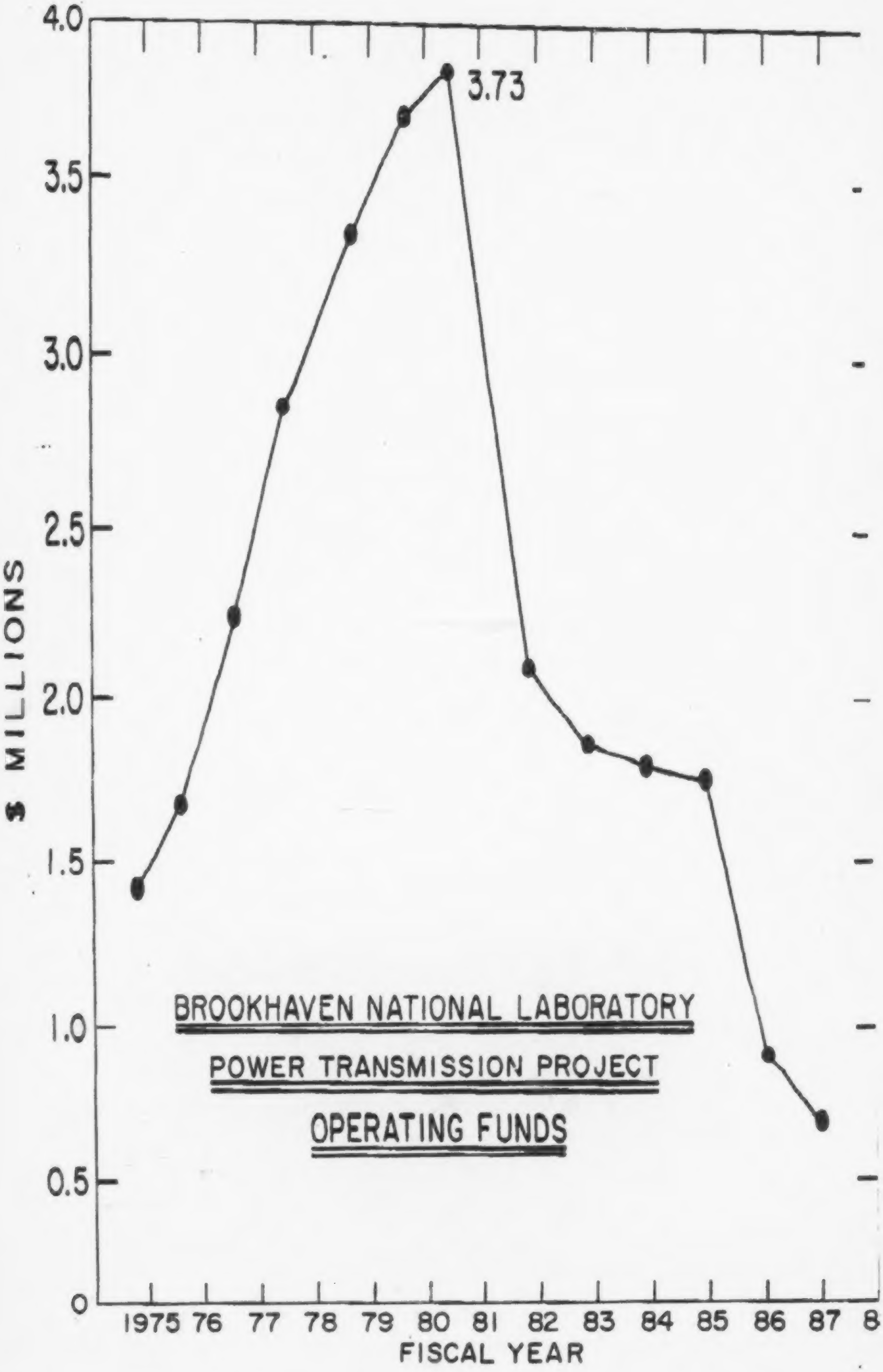


Fig. 3. Flexible superconducting power transmission cable. The cable is taken off the reel for installation in the white pipe seen center-left.

LORD KELVIN'S SOLUTION FOR
THE CHOICE OF CONDUCTOR SIZE
FOR THE FIRST NIAGARA FALLS
GENERATING STATION.





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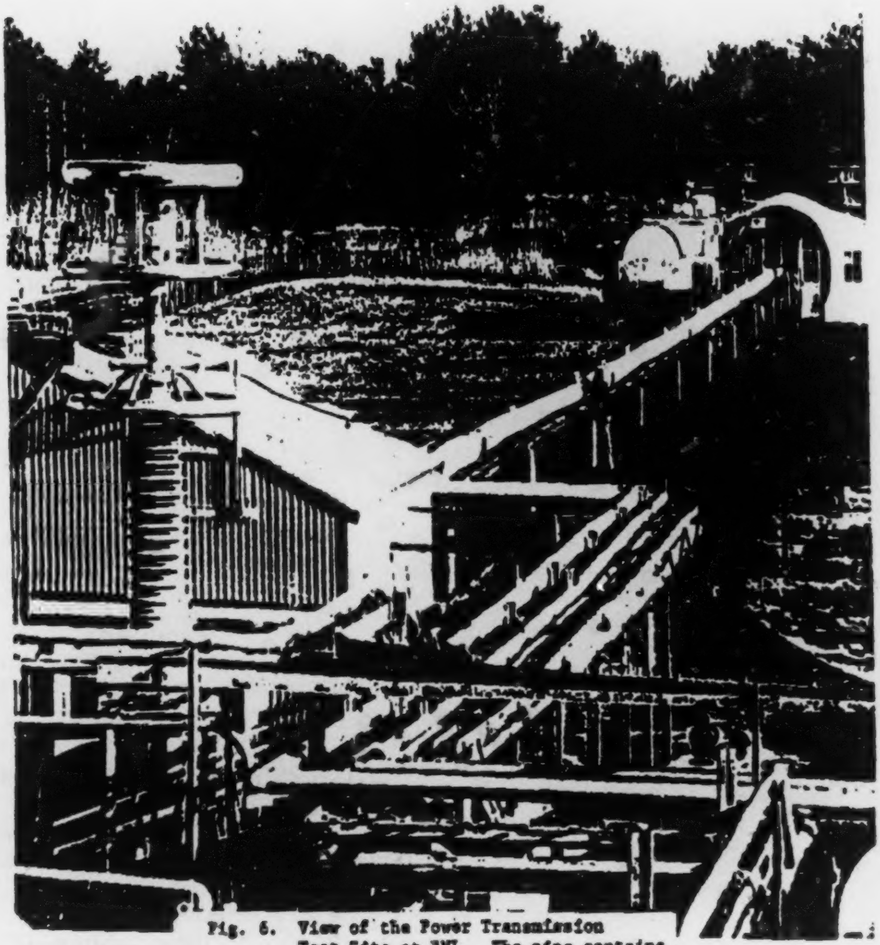

Fig. 6. View of the Power Transmission Test Site at BNL. The pipe contains 2 cables, each with a 330 Megawatt rating.

Senator FORD. Thank you.
Dr. Schriesheim?

STATEMENT OF DR. ALAN SCHRIESHEIM, DIRECTOR, ARGONNE NATIONAL LABORATORY

Dr. SCHRIESHEIM. Mr. Chairman, members of the subcommittee, Argonne National Lab brings extensive expertise and certainly a vested interest to a discussion of S. 1480, and I would like to acknowledge that fact.

Our lab has played a lead role in superconductivity for more than a quarter of a century. The leadership is in part a result of DOE's years as the primary agency in the development of particle accelerators, fusion power, magneto hydrodynamic power generation, and certainly the development of new electrical power systems.

We have worked successfully with our sister national laboratories, university and industry, both in applications of superconductivity, and in the development of basic knowledge on the phenomena.

Since the discovery last winter of the new higher temperature ceramic superconductors, Argonne has made many significant contributions to that field.

Argonne has been directed by the Department of Energy to head a multilab effort to produce a practical superconducting wire, and to direct a survey with several other laboratories on the economic impact of superconductivity.

And due partly to our participation in these cooperative efforts, President Reagan in July just named Argonne as the national superconductivity applications center.

Both my personal experience as a 27-year industrial research executive, and the lab's experience, leads me to endorse the goals of Senate bill 1480.

In fact I testified in March before a House science and technology committee that the Department of Energy should establish some kind of a national superconductivity program, using the national laboratories as a vehicle.

But what I believe is implied by S. 1480 and by the President's 11-point superconductivity initiative is as important as what is specified.

What I mean by that is, most important, the recognition of the need for a long-term commitment of organization and funding.

In my opinion the greatest danger to superconductivity is its popularity. The public enthusiasm has arisen in a very short time almost to the level of a fad.

Public interest that flares is fast and hot and has the potential to fade and cool—we all know that—just as fast. When soaring expectations are not satisfied by the introduction of a superconducting kitchen appliance in 1988, we can only succeed if we have sustained effort over a decade. There is also a clear indication that through initiatives like this bill we aim to change the American research culture.

We cannot expect to duplicate in a few years the kind of integration that it has taken decades to develop in Japan. However, we can and must improve the synergistic exchange between industrial, academic and Federal researchers in this country.

Finally, we have accepted the President's designation of Argonne as the Nation's superconductivity research center for applications as a mandate for flexibility and pragmatism.

Success of the cooperative research centers will be dependent on the same characteristics.

Laymen and some theorists talk about technology transfers as if it were one process. Our experience suggests that it's dozens of processes.

For example, Argonne has led the development of a cooperative program with the steel industry to generate technology which will leapfrog foreign competitors.

We were able to work effectively through a well established trade association in an industry of relatively few corporations.

A very different mode of cooperation was required to help organize agribusiness firms to meet with universities in the Midwest plant biotechnology consortium.

And still another model is needed in our exploratory meetings with the off-road equipment industry.

More recently, Argonne has formed a superconductivity affiliates organization of diverse corporations with common interests.

Clearly every company and industry needs a mode of technology transfer which is suited to its own character.

The importance of flexibility is apparent when you consider the variety of industries and firms that would be affected by higher temperature superconductors.

Argonne's economic analysts estimate that in the next five years we may see high temperature superconductors apply to thin film computer interconnects, magnetic shieldifg of the type used in electronics and MR, imagers, research magnets, and magnets for small motors.

Between five and ten years from now, if all goes well, we can expect to see superconductivity applied in Josephson devices, which form the basic elements of fast electronic switches, sensors, and computer elements.

They could produce high TC power and communications transmission lines, commented on earlier. And we should see new generations of radio frequency cavities of the types used in particle accelerators in communications.

Around the turn of the century, again, assuming things go along, we expect to be competent in large scale applications like power generators, large magnets and motors, magnetic storage, and levitated vehicles.

Well, if we cram all of these industry participants into one well fit model we are going to fail. And both theorists and Federal administrators tend to be more comfortable with conformity to reach specifications which they prescribe.

We need to guard against that tendency.

Mr. Chairman, I detail these caveats only because of the importance of better cooperation between publicly funded research and private industry in superconductivity.

Even granted that it is currently suffering from oversimplification and hype, superconductivity's economic potential is immense.

The President's 11-point initiative and the legislation currently under your consideration can be vital tools to recognize that potential.

Certainly Argonne is already implementing the President's plan, and we stand ready to bring the cooperative research centers to effective reality as well.

I thank you.

[The prepared statement of Dr. Schriesheim follows:]

Written Testimony of Dr. Alan Schriesheim, Director
Argonne National Laboratory
before Energy Research and Development Subcommittee
Senate Committee on Energy and Natural Resources
on S.1480 September 15, 1987

Mr. Chairman and members of the Subcommittee:

Argonne National Laboratory brings extensive expertise and a vested interest to discussion of S.1480. Let me start by openly acknowledging that fact.

My laboratory has played a lead role in superconductivity for more than a quarter century. This leadership is, in part, the result of DOE's years as the primary agency in the development of particle accelerators; plasma containment for fusion power; magneto-hydrodynamic power generation; and development of new, more energy efficient systems for the transmission, storage and use of electrical energy. We have worked successfully with other major research facilities -- our sister national laboratories, universities and industry -- both in application of superconductivity to these specific problems and in the development of basic knowledge on the phenomena.

Since the discovery last winter of the new higher temperature ceramic superconductors, Argonne has made significant contributions to that field. They include confirmation that the early lanthanum-strontium-copper-oxygen ceramic remains superconducting in the presence of a strong magnetic field, formation of the first yttrium-barium-copper oxide single crystals and the first characterization of its molecular structure, the first superconducting wire made of the new materials and the first conference for industry on the new superconductors to be held at a national laboratory.

Argonne has been designated by the Department of Energy to head the multi-laboratory effort to produce a practical superconducting wire in the next five years. Our technical evaluations group directed the efforts of several national laboratories to survey the economic impact of superconductivity. Due partly to our past history and participation in these cooperative, coordinated efforts, President Reagan in July designated Argonne as the national Superconductivity Research Center for applications.

Before coming to Argonne five years ago, I spent 27 years managing research for an industrial corporation, Exxon. During my Argonne tenure, I have put a high priority on fostering better relations with industry and speeding the transfer of technology from both basic and applied research to the private sector.

All that experience -- both my personal experience and the Laboratory's experience -- leads me to endorse the goals of Senate Bill 1480. In fact, I testified in mid-March before a House Science and Technology Subcommittee that the Department of Energy should establish a national superconductivity R&D program, using the national laboratories as a vehicle. As I said at that time, "It is logical to organize one program accountable for coordination of effort and liaison with industry."

There are two primary reasons why the establishment of Cooperative Research Centers should be considered in conjunction with the President's designation of Argonne as the Superconductivity Research Center for applications and with the development of other appropriate federal research programs.

One is that the pressure on corporations to show short-term profit performance is going to prevent most companies from the heavy commitment of R&D funding to assure earliest commercialization of superconductivity. The second is that other countries with historically better integration of their public and private research networks are demonstrating their will to beat us to this immense market.

Our experience since the superconductivity breakthrough in December clearly indicates that national laboratories are the logical focus of cooperative research programs in this field. Only at multi-program labs like Argonne do we have the mix of disciplines; the combination of theorists, experimentalists and engineers; and the giant user research facilities like Argonne's Intense Pulsed Neutron Source which have already proven important in characterizing the atomic structure and developing improvements in these materials.

But what is implied by S.1480 and by the President's 11-point superconductivity initiative is as important as what is specified.

Most important is the recognition of the need for a long-term commitment in organization and funding. In my opinion, the greatest danger to America's superconductivity effort is its popularity. Public enthusiasm has risen in a very short time almost to the level of a fad. Superconductivity is the latest buzz word. And public interest that flares up this fast and this hot has the potential to fade and cool just as fast, when soaring expectations are not satisfied with introduction of superconducting kitchen appliances within a year.

In America we rarely commit several generations to construction of a cathedral. We pride ourselves instead on putting up skyscrapers in a few months. Realizing the benefits of superconductivity may not require generations, but it will certainly require years. We can only succeed if we have sustained support over a decade.

There is also a clear indication that through initiatives like this bill, we aim to change the American research culture. We cannot and should not expect to duplicate in a few years the kind of integration between industry, academia and the federal government that it has taken decades to develop in Japan. However, we can and must improve the synergistic exchange between the three major types of research in this country.

In the past, industry, academia and the national laboratories have eyed each other suspiciously as competitors. They sometimes addressed problems of science and technology from such different viewpoints that they seemed not to speak the same language. We at Argonne are dedicated to opening the channels of communication and cooperation within this national research community. S.1480 can be a step in that direction.

Finally, we have accepted the President's designation of Argonne as the nation's Superconductivity Research Center for applications as a mandate for flexibility and pragmatism. Success of the Cooperative Research Centers will be dependent on the same characteristics. Laymen and some theorists tend to talk about "technology transfer" as if it were one process. Our experience proves that it is dozens.

For example, over the last three years, Argonne has taken the lead in development of a cooperative program with the steel industry to generate technology which will leapfrog foreign competitors. We were able to work effectively through a well-established trade association in an industry of relatively few corporations.

A very different mode of cooperation was required to help organize agribusiness firms and major universities into the Midwest Plant Biotechnology Consortium. We found still another model was needed in our exploratory meetings with the off-road equipment industry. More recently, Argonne formed a Superconductivity Affiliates organization of diverse corporations with a common interest.

Argonne can testify that a Cooperative Research Center will only succeed if it takes into account the size of the firms involved, their financial health and reserves, the degree of institutional cooperation already established within the industry and even their marketing skills. We have to be ready to deal with individual firms, small groups of firms in consortium or industry-wide groups. Clearly, every company and industry needs a mode of technology transfer which is suited to its own character.

The high priority which flexibility must assume is apparent when you consider the variety of industries and firms that will be affected by higher temperature superconductors.

Argonne's economic analysts estimate that in the first five years -- between now and 1992 -- we may see high temperature superconductors applied to thin film computer interconnects, magnetic shielding of the type used in electronics, nuclear magnetic resonance imagers, research magnets, magnetic separators and magnets for small motors.

Between 5 and 10 years from now, we can expect to see superconductivity applied in Josephson devices which form the basic elements of fast electronic switches, sensors, amplifiers and computer elements. We could see high Tc power and communications transmission lines. We could also expect to see new generations of radio frequency cavities of the types used in particle accelerators and communications.

Around the turn of the century, we should begin to be competent in the large-scale applications like power generators, large magnets and motors, energy storage and levitated vehicles.

Although the market impact will be felt in these various industries on this varying time scale, planning, research and development in most of them will have to go forward simultaneously. Obviously, we are talking about capital goods and consumer goods firms, big and small ones, widely varying access to finance, and a wide spectrum of managerial mind-set.

If we try to cram all industry participants into one "will-fit" model, we are going to fail. And both theorists and federal administrators tend to be more comfortable with conformity to rigid specifications which they prescribe. We must guard against that tendency.

Mr. Chairman, I detail these caveats only because of the importance of a better cooperation between publicly funded research and private industry in this accelerating area of high temperature superconductors. Even granted that it is currently suffering from oversimplification and "hype", superconductivity's economic potential is immense.

The President's 11-point initiative and the legislation currently under your consideration can be vital tools to realize that potential. Argonne already is implementing the President's plan. We stand ready to bring the Cooperative Research Centers to effective reality, as well. Thank you.

HWC:pc (9/9/87)

Senator FORD. Thank you.
Dr. Finnemore?

STATEMENT OF DR. DOUGLAS K. FINNEMORE, PROFESSOR OF PHYSICS, IOWA STATE UNIVERSITY OF SCIENCE AND TECHNOLOGY

Dr. FINNEMORE. Mr. Chairman, my name is Douglas Finnemore. I am a professor of physics at Iowa State University, and represent the university scene. I have a prepared statement which I would like to put in the record.

Senator FORD. Your statement will be included in the record.

Dr. FINNEMORE. Many of the points which are in our prepared testimony have been made by other people, particularly those having to do with intellectual property and patents and so on.

One issue which I think is important to realize is that in these superconducting materials, when you have seen one, you have not seen them all.

There is a great diversity of properties and characteristics. And when you begin to commercialize superconductivity, each application has its own materials problem to solve, and different kinds of consortia would be appropriate for solving the various problems.

I think it is quite important that you not only think large corporations entering this field, but the small corporations, any science corporation, be available for it.

Just a word about superconductivity and where we are. Paul Chu discovered superconductivity at 95 Kelvin. Within a couple of weeks Bell Labs had the phase and crystal structure.

There were just dozens of experiments done in a few weeks. A lot of the basic properties were known. High critical fields, for example, there was a big breakthrough when IBM announced that you could get a million amps per square centimeter.

So the big three were known, of temperature, field and current.

But being there, an analogy I made in the written testimony, is sort of like a football scout for a college team spotting a high school kid who as it turns out can run 40 yards in 3.6 seconds.

That is a tremendous achievement. But speed and weight does not a halfback make. We simply have all these other properties that you have to get straight.

If you are going to make superconducting chips, the superconductor has to be compatible with the other elements on the chip. It has to be able to be processed at low temperatures, so you can use photolithographic techniques, and all these submicron facilities which were talked about by the Congressman.

If you are going to make magnet wire, you have to form it in terms of very long, thin fibers and filaments. It is really quite different processing techniques, and it is unrealistic to think that one organization is going to undertake and do all of this.

So I would think that in your thinking about this, that lots of players be in the game.

One of the recommendations that I would like to point out is, I am professor of physics. I am also associate director of the Ames Laboratory, which is one of the national labs. And I am also acting director of the Center for New Industrial Materials, until we find a permanent director.

Thus, a Department of Commerce initiative to help get technology transfer moving, and it is important that organizations like ours, not just ours but organizations like ours, where the major superconductivity effort can be a player in the game; it's just not totally multiprogram labs that are in it. Thank you.

[The prepared statement of Dr. Finnemore follows:]

Testimony of

Dr. Douglas K. Finnemore
Professor of Physics
Iowa State University of Science and Technology

Regarding

S 1480
Department of Energy National Laboratory
Cooperative Research Initiatives Act

Before

Energy and Natural Resources Committee
U.S. Senate

September 15, 1987

Mr. Chairman, my name is Douglas Finnemore and I am a professor of physics at Iowa State University. In that capacity, I also serve as the Associate Director for Science & Technology of the DOE owned, university operated Ames Laboratory, and as the Acting Director of the Center for New Industrial Materials, a U.S. Department of Commerce initiative to stimulate intermediate range applied research. In addition, my personal research for the past 25 years has focused on the study and development of new materials, especially superconducting materials.

I am here today representing Iowa State University, a medium sized land grant university with a strong interest in the development and transfer to industry of new materials. As background on Iowa State University, let me just quickly list some of the university's accomplishments in the area of materials processing and development.

Iowa State University researchers, working in cooperation with the DOE and its predecessor agencies, have developed the processes for producing most of the rare earth elements, which are critical to superconductors, as well as over half of the metals on the periodic table. Iowa State University researchers, for over 40 years, have been the developers of new materials with unique properties, such as terfenol D and the new high strength copper base alloy. These materials, and related scientific advancements, have made major contributions to the nation's materials industry and related instrumentation companies.

These R&D efforts continue today. At present, Iowa State University, in cooperation with the Department of Energy, the Department of Commerce and private industry, has major research efforts in superconductivity. There is a special emphasis on new materials development and the transfer of these materials to industry. Our plans producing such materials in useful configurations, such as superconducting wire.

State of Superconducting Knowledge Base

Since the initial discovery of superconductivity at 95 Kelvin, our understanding of the materials has increased very rapidly. Within a few weeks, the phase was isolated and the crystal structure was determined. In addition, measurements of a whole battery of the physical properties were made and it was shown that the materials remain superconducting to very large magnetic fields. A few months later, materials were made that could carry millions of amperes per square centimeter, the very high current densities needed for both microelectronic and magnet applications. Thus, for the three key variables of temperature, magnetic field and current carrying capacity, we know it is possible. Progress has truly been remarkable. –

There is, however, an enormous task yet to be done. If I could use an athletic analogy, the situation is similar to a college football scout who has discovered a 200 pound kid who can run the 40 yard dash in 3.6 seconds. This is a tremendous achievement but it takes a great deal more to be a halfback. The athlete has to be able to turn on a dime, follow blockers effectively, take the physical punishment and in some cases, even pass the University entrance exam.

The situation is similar for the new superconductor. We have this remarkable new material. For it to be useful in microelectronics, however, the material has to be compatible with other materials in the circuit; it must be capable of being processed at temperatures call for expansion in the superconductivity program, both for the development of a knowledge base for processing and in the development of new superconducting instruments.

It is from this perspective that Iowa State University comes here today, to support the National Laboratory Cooperative Research Initiative Act. The basic premise of the bill seems to be that there is a need for the development of cooperative research ventures under the leadership of and closely integrated into the DOE laboratory research system. These cooperative research ventures appear to involve the establishment of non-profit research centers, capable of receiving up to $10,000,000 in non-appropriated funds, which will focus on the development and rapid transfer of new superconducting materials. According to the bill, these cooperative efforts would be based at one of the several multi-program USDOE laboratories, and they would involve cooperative efforts with industry and universities.

The concept of establishing independent cooperative research centers closely affiliated with DOE laboratories is a creative approach to solving the problem of how to best link our national research capacity with industrial interests. Such cooperative research is common place on a large scale in Japan and Europe and usually involves both federal facilities and financial resources. Such efforts, if carefully planned and realistically scoped, could be a useful means of speeding the creation and transfer of new superconducting materials to industry.

In thinking about how to best implement the general concept of S 1480, we have several general recommendations. Before reviewing these, let me first present some of my thoughts on the state of the knowledge base for superconducting materials and the state of the art for compatible with photolithographic techniques; it has to be made with very high reliability; it must be robust in service.

In the case of magnet conductors, the material has to be processed in the form of long cables; it must have effective current transfer to the stabilizing conductor; it has to withstand high stresses, it has to be reliable and reasonably rugged. These are but a few of the areas where research can have a major payoff.

In all of this work, effective material processing procedures which can be done at a reasonable cost are the key to success. It is critical to build the knowledge base in chemistry, physics, metallurgy and ceramics that is needed to make these materials in many different forms. The people who understand the materials and the processing will control the emerging technologies.

A key point to remember in planning the development of these materials is that there are many potential applications. Each application has special requirements for materials processing. Each application will utilize a different combination of the unusual properties of these materials. For example, the applications of computer interconnects, highly sensitive signal detectors and large scale magnets for Magnetic Resonance Imaging (MRI) depend on very different properties of the superconductor. Therefore, it is essential to maintain a long term R&D effort to learn the fundamentals of the phenomena and to develop the knowledge base for materials processing for each application.

Recommendations for S 1480

We are still years away from the first large scale commercial use of new superconducting materials. This fact must be considered in all policy planning, yet the products have a good chance of playing a major role in our future economy. As a result of this fact, the development of public policy that encourages cooperative (industry/university/government) research arrangements is an important first step in speeding the process. We support this policy effort and offer the following comments and recommendations.

S 1480 Places Too Much Emphasis on Large Corporations

Large technology based corporations, such as Westinghouse, GE, IBM and others, will certainly be important actors at all stages of the commercialization process for the yet to be developed new superconductors. These corporations, however, may not be the sole industrial actors in the research and early development stages of superconductor development. History and a survey of present activities in this field of materials development tell us that it will often be the small firm, such as Hypres, Inc. with their development of superconducting high speed oscilloscope, that will play a critical role in the development of this technology. Indeed, much of the superconducting wire manufactured in the United States has been made by rather small companies, such as Intermagnetic General Corporation and Supercon, Inc.

Recommendation 1: **S 1480 should encourage and provide mechanisms for the participation of smaller scale R&D firms.** This will involve more careful assessment of the roles and responsibilities of the government and the larger corporations so that the smaller firms can participate and survive.

S 1480 Permits Center Development at Multi-Program Labs Only

At present, this bill is designed to focus on the development of linkages between the DOE multi-program labs and the creation of new cooperative research centers within these programs. This emphasis overlooks the fact that such cooperative centers can also be developed around other DOE facilities and organizations. For instance, the Ames Laboratory, which Iowa State University operates for DOE, is not classified as a multi-program laboratory. At the same time, Ames Laboratory is the nation's center for rare-earth research and information. It maintains a large superconducting materials R&D effort and already has in place, through its Center for New Industrial Materials, the framework, facilities and some funding for just such a cooperative center. As such, we feel that by limiting the provisions of the bill to only DOE multi-program laboratories, major national resources, such as the Ames Lab and the Center for New Industrial Materials, may be lost.

Recommendation 2. The establishment of cooperative research centers within the DOE research laboratory system should be possible at all DOE facilities involved in superconducting materials research and not limited to the multi-program labs. These labs should be identified by name.

Intellectual Property Rights are Ill-defined in S 1480

In an effort to ease the concern about who owns the intellectual property produced in one of the proposed cooperative centers, S 1480 seems to suggest that such products will be publicly available. While there do need to be mechanisms for assuring attempts to commercially develop new superconducting materials, it has been our experience that those companies cooperating in such centers must have some ownership of the product if success is desired. Industrial participants in cooperative centers need to have first rights of refusal on intellectual properties produced and also special licensing provisions for those properties they choose to develop.

Recommendation 3. S 1480 should include provisions for the transfer of the rights to new superconducting materials to private industry such that they will invest and participate in the RD&D effort more fully.

In summary, we support S 1480 and are prepared to develop and organize cooperative efforts to stimulate, over the next 10-15 years, superconducting RD&D materials.

Senator FORD. Thank you, Dr. Finnemore.

Dr. Hecker.

STATEMENT OF DR. SIEGFRIED S. HECKER, DIRECTOR, LOS ALAMOS NATIONAL LABORATORY

Dr. HECKER. Thank you, Mr. Chairman. Thank you for allowing me the opportunity to express my views on Title I of Senate bill 1480.

I also have a written statement that I would like to submit for the record.

Senator FORD. It will be included in the record.

Dr. HECKER. Thank you.

As has already been discussed, the scientific breakthroughs in superconductivity have been mentioned. The enormous potential for applications has been mentioned, including the race for commercialization for high temperature superconductors is on.

But I would like to address in my remarks, to tell you what I believe it is going to take to exploit the research that has been done.

I think that we as a Nation will need to work all aspects of what I would like to call the innovation cycle, and that is, the research, the development, the manufacturing, and the marketing and distribution.

I think it is particularly important today, more so than ever before, because the time span from invention to actual application has been decreased substantially in the past ten year timeframe.

And so now many of these steps need to be worked in parallel rather than in series.

And also, secondly, the international competition is fierce. I think the Japanese are particularly well suited to try to exploit the commercial application of the new superconductors.

Senate bill 1480 addresses one of the key areas, and that is, of applied research and development, enabling technologies.

These enabling technologies are primarily in the area of material synthesis and processing. These include areas such as thin films and coatings, powder synthesis consolidation and centering, bulk processing, and a number of others.

That such work on enabling technologies I believe has the promise to drive down the precompetitive front end costs that the private sector faces in trying to exploit this technology.

As has also been stated earlier, much of the difficult work in these areas remains to be done before we will see widespread applications in superconductivity.

To be competitive as a nation, we must use all of our sectors, industry, universities as well as the national laboratories, some of our private companies, especially the large ones such as IBM and AT&T are well poised in research and technology development.

However, that is not the case for most of the small and medium sized companies. Universities are primarily research oriented, although certainly, a number of centers and spinoff companies have also addressed the application orientation.

The national laboratories, in my opinion, are intimately involved and well suited for both research and technology development.

Bill 1480 suggests that we use the national labs as resources in helping to commercialize these high temperature superconductors. And I certainly concur with this concept.

The labs have excellent credentials in superconductivity research, as has already been pointed out, and also, with practical experience of superconductor applications.

They are well suited to contribute in enabling technologies, as I discussed earlier. They have excellent facilities for research and technology.

And unlike some of the detractors of the national labs would say, some of the labs do have excellent environments for innovation and for technology transfer.

And I would like to turn specifically to my own institution, the Los Alamos National Laboratory. As you well know, our primary business is research and development in national security, and particularly in nuclear weapons and some nonnuclear concepts such as SDI and advanced conventional munitions.

In our nuclear weapons work we have one of the best examples of technology transfer in this Nation. And that is, we do the research, we do the development, we do the design. We interface with the production complex on a daily basis.

In fact this involves thousands of interactions during the course of a year. And we take care of the customer interactions, that is, the interactions with the military.

This process works, and I maintain it works extremely well. We have helped to maintain this Nation's nuclear deterrent over the past 40 years.

Now, one could ask the question, why should we become involved with the private sector? First, I would like to answer that by saying that we already are heavily involved in non-defense research and development at Los Alamos.

In 1987 alone, we had nearly $200 million worth of R&D in the nonmilitary sector. That's a necessity in order for us to maintain a first rate scientific institution.

That also gives us the opportunity to contribute to other important national problems.

Now, much of the capability that we've developed at Los Alamos is indeed applicable to both military as well as civilian problems. In fact, in my own opinion, the U.S. can no longer afford to fight wars on two technological fronts, that is, the military on one hand, and the commercial on the other, to fight those separately.

We must learn how to leverage the technologies better. Los Alamos also has an excellent record in superconductivity research as well as in development.

We have been involved in what was the previous craze in superconductivity, the so-called heavy Fermian superconductivities.

And we have been involved over the years in practical applications including superconducting magnetic energy storage, as well as a DC power transmission line project.

And today we are heavily involved in all aspects of high temperature superconductivity research. And some of our first applications in my opinion will likely come in the development formula you use.

And I think this will give us the experience that should be able to accelerate commercial applications.

Let me turn specifically to the concept of the centers for enabling technologies.

I think in order for applied R&D in enabling technologies to be useful to industry, it was just stated that the labs must be tied to the market pull of the private sector.

I think that is extremely important. We must develop new partnerships between the laboratories and industry, as has already been pointed out.

The proposed centers, in my opinion, would allow us to establish such new partnerships.

I developed the idea of specific centers and what one would do with them in more detail in my written statement. But I would just like to summarize that briefly, at least the way I would see it.

The centers would be located at the DOE laboratories that have demonstrated excellence in superconductivity research, as well as having a record of technology development, especially in the area of materials technology.

I think a participation by universities that meet the same criteria should also be considered. And such centers, to be useful, in my opinion, would have to be funded at the level of perhaps $3 to $5 million per year in operating funds, and that industry would be allowed to participate by guiding and cosponsoring work in generic technology areas.

And then perhaps by fully sponsoring development work that is more product specific.

I see the centers as establishing the new relationships between industry and the laboratories that I have mentioned.

Now, the Secretary of Energy, as has already been pointed out, has indicated that new and more productive relationships must be established.

And he has asked us at Los Alamos to explore industry interest in developing such new relationships. The preliminary results of that are very encouraging. We have met with a number of private companies to explore technology partnerships, and they have shown some very great interest.

I have also been in contact with my colleagues at the DOE national laboratories to try to ascertain what their interest level has been from industry.

The companies that have interacted with us have pointed out a need for at least two things to occur for these technology partnerships to be useful for them.

And that is, first of all, again, the early involvement of industry in the research and development at the laboratories. And second, what I would call, making the laboratories more user friendly, and that is, in all areas of contracting, patenting, licensing, and the entire business of paperwork.

Senate bill 1480 would encourage the labs, in my opinion, to follow an aggressive course with industry, and hopefully provide the necessary funding to make it happen.

I want to reiterate two final points. And that is, that Senate bill 1480 addresses only one part of the overall superconductivity challenge, but it's a very important one.

And second, that it does not establish new capabilities from scratch, at the DOE laboratories, at the expense of other sectors. Instead, it builds on existing capabilities that I believe we cannot afford to ignore in trying to meet this important challenge.

And so that a small investment will be highly leveraged by building on these capabilities at the national laboratories.

So let me close by thanking you, Mr. Chairman, for allowing me to express my views.

[The prepared statement of Dr. Hecker follows:]

U.S. SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

HEARING ON
DEPARTMENT OF ENERGY NATIONAL LABORATORY COOPERATIVE RESEARCH INITIATIVE ACT

Statement by
Siegfried S. Hecker, Director
Los Alamos National Laboratory
September 15, 1987

I. INTRODUCTION

The scientific discovery of a new class of materials that is superconducting (able to conduct electricity without energy loss) above the boiling point of nitrogen will revolutionize many technologies and create many new applications rivaling those of the transistor and the laser. The United States played a pivotal role in the discovery of the new ceramic oxide superconductors. The response of the U.S. research community since the initial discovery has been exemplary. Our nation's scientists are leading the way in the search for a fundamental understanding and in pushing the limits even higher with new modifications or new materials.

Potential applications are almost limitless. They range from levitated magnetic trains to faster supercomputers. The race for commercialization is on. It will not wait for a better fundamental understanding nor for new materials. Is the U.S. ready to exploit its lead in superconductivity research, or will the commercialization of superconductors suffer the same unfortunate fate as that of computer microchips and many electronic consumer products such as VCRs?

To survive in this highly competitive field, the U.S. must use its conventional strengths: a basic research community that is second to none, a government highly supportive of science and technology, and a free-market industrial base able to respond to new consumer and defense needs. However, to excel we must forge new partnerships among the major sectors of science and technology: universities, federal laboratories, and industry. Several initiatives from the National Science Foundation are exploring university-industry partnerships. Senate Bill 1480 would establish interaction of universities, industry, and the DOE national laboratories by establishing centers for research in enabling technologies at the DOE laboratories.

The national laboratory-university interactions in the area of superconductivity have been very good and must be encouraged to continue. In my testimony, I describe how what I call centers for exploratory R&D would forge new national laboratory-industry partnerships. The area of high-temperature superconductors is ideal for establishing such partnerships.

II. SCIENTIFIC BREAKTHROUGH

To fully appreciate and understand the significance of events in the development of superconductors over the last eight or nine months, it must be viewed from the perspective of 75 years of research effort. Superconductivity was discovered in 1911 in the element mercury by the Dutchman Kammerling Onnes, starting a 75-year quest to discover and develop materials which would display this property at even higher temperatures.

Onnes's discovery of superconductivity was at a temperature of 4 K, only slightly warmer than absolute zero, and in the following 75 years the scientific community had managed to raise that temperature by only 20 degrees to about 24 K, which is still far from the ideal goal of room temperature (293 K). The 20-degree improvement was the result of painstaking research by hundreds of scientists studying a myriad of different materials and atomic structures and was gained at a steady but slow rate over the years between 1911 and 1986. Although several superconducting properties are important in the practical application of superconductors, for example, the ability to carry large electric currents and to function in high magnetic fields, the single most significant factor in evaluating their impact on our way of life is the temperature at which superconductivity begins. Thus, the major research emphasis over the years has been directed at raising this temperature. From this perspective (i.e., progress at the rate of a two- or three-degree increase in critical temperature per decade) a gain of over 70 degrees in less than a year represents an unprecedented and enormous scientific breakthrough in this field with far-reaching implications.

The first stage of this breakthrough was announced to the scientific community in October 1986. Researchers at IBM-Zürich published results which showed that a compound of lanthanum, barium, copper, and oxygen exhibited superconductivity at nearly 30 K. While the observation of superconductivity in oxides is more than a decade old, earlier studies in other oxides had not produced very interesting results. From this point on, progress has been nothing less than spectacular. In only two months, researchers in the United States, Japan, and China had shown that by substituting the element strontium for barium in the above material, the onset of superconductivity was raised to almost 40 K. Researchers at the University of Houston had reached temperatures of over 50 K by the application of high pressure. While these results represented an unprecedented breakthrough relative to the historical development, even more astounding progress awaited researchers. In February, scientists at the University of Houston and the University of Alabama announced the discovery of superconductivity at a temperature of 93 K in an oxide of yttrium, barium, and copper. Other scientists, including those at Los Alamos, rapidly showed that superconductivity above 90 K was possible with a variety of other elements replacing yttrium, including some (such as gadolinium) which would normally be expected to destroy superconductivity.

The emphasis of basic research in this field is now twofold. The search continues for even higher critical temperatures (currently at 98 K), and there is every reason for continued optimism in this direction. However, it has also focused on developing an understanding of superconductivity in these new materials and characterizing the effects that the new arrangement of atoms (crystal structure) will have on the development of technological applications. While several theories have been advanced to explain the superconducting behavior of these materials, it has yet to be determined whether or not the actual mechanism is the same as in other classes of superconductors. Although this type of basic research is essential to developing an understanding of the physical principles governing this behavior, we cannot afford to hold up the pursuit of applications while we build such an understanding.

There is another aspect of this breakthrough, quite apart from the astounding increase in critical temperature, which is worth noting. That aspect is the extremely rapid rate at which many laboratories have been able to reproduce and confirm these exciting discoveries. Over the last 20 to 25 years, incremental improvements in critical electrical applications and electronic devices. Both of these areas will find broad application in both the consumer sector of the economy and the defense establishment. In the first area, a wide variety of applications with the potential for saving vast sums of money is evident. Superconducting electric power transmission would eliminate much of the power loss associated with the electrical resistance of conventional transmission lines with very large economic benefits. Superconducting magnetic energy storage would permit more efficient use of our nation's generating capacity by storing energy during periods of low demand to use during periods of peak load. The application of superconducting generators may improve the generating efficiency itself. In terms of actual resource conservation, it is possible that the new superconductors may have their largest impact in the electric power arena. Additional applications such as superconducting electric motors, energy storage for automobiles, transportation (levitated trains, for example), medical diagnostics, and other scientific research equipment abound and will no doubt grow as the properties and availability of these materials improve.

The impact of these new materials on the electronic device industry may be even more profound and is very likely to occur more rapidly than the high-power applications. The use of these materials in electronic applications will stress the superconducting properties to a lesser extent than applications such as electric power transmission or storage. Their use as replacements for many semiconductor components and as the interconnecting material between these components may revolutionize computer speed and performance. This use is likely to extend into many applications where microwave signals must be carried from one component to another.

Although drawn from both of the above categories, defense applications are of such importance to the nation that they warrant separate consideration. In this area, development of applications is a relatively new direction for superconducting materials, and the examples given here only represent the tip of what may develop. The single largest impact may result from the use of superconducting devices in supercomputers, electronic components for improved speed and quality in signal processing, microwave applications, and sensor development. In addition to producing large performance increments in these devices, the superconductors will very likely be much more resistant to damage from nuclear radiation than the semiconductor components they replace, even those we currently consider radiation hard. In the strategic defense arena, applications to the neutral particle beam are already being studied. These include magnets, radio-frequency accelerating cavities, and magnetic shielding. Additional applications could include high-power transmission between components and magnetic energy storage to meet the high-power, short-term demands of battle. In the more traditional arena, the reduced dimensions and weight of a superconducting electric motor may have a significant impact on some aspects of naval propulsion.

IV. THE RACE TO COMMERCIALIZE

"Superconductivity has become the test case of whether the United States has a technological future," said Frank Press, President of the National Academy of Sciences. The ingenuity of our researchers and the almost unlimited potential for applications are clear for superconductors, but now we must be able to commercialize our scientific discoveries if we are to remain economically competitive.

To capitalize on this opportunity, in the face of intense international competition, we require a concerted effort that links the capabilities of our nation's industries, universities, and national laboratories. Our principal competition will come from Japan.

temperature have frequently occurred in materials which are very difficult to produce, and confirmation by others has been difficult and slow. Although the synthesis of these new materials is complex and only partially understood, most laboratories have been successful in producing materials with similar behavior relatively quickly. The significance of this is twofold and of considerable importance. First, it allows a very large number of researchers to quickly and successfully focus their efforts in this area, and secondly, it suggests that these materials are not inherently difficult to synthesize--, an aspect important in their further development for applications. The foregoing statement, however, should not be interpreted to minimize the difficult task of moving from the synthesis of laboratory samples of superconducting material to a fabricated conductor or thin film with optimized superconducting properties in a useful engineering configuration.

III. POTENTIAL FOR TECHNOLOGICAL APPLICATIONS

Of the many potential applications for superconductors which will be described below, only a very limited number has reached the marketplace in any form. The most widespread use consists of superconducting magnets for research applications. The use of superconductors in this application has brought the capability for performing experiments in large magnetic fields within the economic realm affordable by most laboratories, large and small. Superconducting magnets have also been applied successfully to the technology of particle accelerators along with superconducting radio-frequency cavities. In the area of electronic devices, superconductors have been successfully developed for information storage applications. No commercial development of large-scale applications has occurred, but several demonstration projects such as the Japanese levitated train and the Los Alamos designed magnetic energy storage system for the Bonneville power line have been carried out.

Despite their limited use at present, the potential of superconductors for a wide variety of commercial and military applications has been understood for many years. The general lack of widespread use evident above results from the necessity of operating at temperatures close to absolute zero. The tremendous technological implications of this recent breakthrough result mostly from the unprecedented increase in operating temperature and the resulting reductions in cost and weight of refrigeration equipment required to maintain a temperature compatible with the required superconducting properties. Although the difference between the temperature of liquid helium (4 K) and that of liquid nitrogen (77 K) does not seem that large (remembering that room temperature is 293 K), the effect on refrigeration is enormous, both in terms of capital investment in equipment and in the amount of energy expended in operating that equipment. For military applications this reduction in refrigeration translates into a substantially reduced weight penalty. Also of technological significance is the dramatic increase in the strength of the magnetic field in which these materials can be used. This will be particularly important for magnetic energy storage since the stored energy increases with the square of the magnetic field, as well as making possible higher field magnets for research, medical, and particle accelerator applications. In addition to providing superconducting properties which will make applications a part of our everyday life, nature has been kind in the selection of the requisite starting materials. The constituents of which these superconductors are formed are sufficiently inexpensive that raw material costs should not impede their technological exploitation.

The potential applications that may become economically feasible as a result of the breakthroughs of the last nine months fall into two broad categories: high-power electrical applications and electronic devices. Both of these areas will find broad application in both the consumer sector of the economy and the defense establishment. In the first area, a wide variety of applications with the potential for saving vast sums of money is evident. Superconducting electric power transmission would eliminate much of the power loss associated with the electrical resistance of conventional transmission lines with very large economic benefits. Superconducting magnetic energy storage would permit more efficient use of our nation's generating capacity by storing energy during periods of low demand to use during periods of peak load. The application of superconducting generators may improve the generating efficiency itself. In terms of actual resource conservation, it is possible that the new superconductors may have their largest impact in the electric power arena. Additional applications such as superconducting electric motors, energy storage for automobiles, transportation (levitated trains, for example), medical diagnostics, and other scientific research equipment abound and will no doubt grow as the properties and availability of these materials improve.

The impact of these new materials on the electronic device industry may be even more profound and is very likely to occur more rapidly than the high-power applications. The use of these materials in electronic applications will stress the superconducting properties to a lesser extent than applications such as electric power transmission or storage. Their use as replacements for many semiconductor components and as the interconnecting material between these components may revolutionize computer speed and performance. This use is likely to extend into many applications where microwave signals must be carried from one component to another.

Although drawn from both of the above categories, defense applications are of such importance to the nation that they warrant separate consideration. In this area, development of applications is a relatively new direction for superconducting materials, and the examples given here only represent the tip of what may develop. The single largest impact may result from the use of superconducting devices in supercomputers, electronic components for improved speed and quality in signal processing, microwave applications, and sensor development. In addition to producing large performance increments in these devices, the superconductors will very likely be much more resistant to damage from nuclear radiation than the semiconductor components they replace, even those we currently consider radiation hard. In the strategic defense arena, applications to the neutral particle beam are already being studied. These include magnets, radio-frequency accelerating cavities, and magnetic shielding. Additional applications could include high-power transmission between components and magnetic energy storage to meet the high-power, short-term demands of battle. In the more traditional arena, the reduced dimensions and weight of a superconducting electric motor may have a significant impact on some aspects of naval propulsion.

IV. THE RACE TO COMMERCIALIZE

"Superconductivity has become the test case of whether the United States has a technological future," said Frank Press,[1] President of the National Academy of Sciences. The ingenuity of our researchers and the almost unlimited potential for applications are clear for superconductors, but now we must be able to commercialize our scientific discoveries if we are to remain economically competitive.

To capitalize on this opportunity, in the face of intense international competition, we require a concerted effort that links the capabilities of our nation's industries, universities, and national laboratories. Our principal competition will come from Japan.

The Japanese will clearly organize their resources on a national scale. While we in the U.S. debate the merits of federal involvement, the Japanese government has already begun to function in its usual role as facilitator and coordinator. In less than two weeks after the February 16 announcement by Professor Chu of the University of Houston, the Japanese government's Science and Technology Agency set up a committee on superconductivity with more than 100 member organizations. The powerful Ministry of International Trade and Industry (MITI) also formed a committee of industry and government laboratory researchers.

To date, the amount of federal funding by the Japanese appears to be modest. Their industries, however, have entered the technological race with great enthusiasm. And, as noted above, the government is playing a pivotal coordinating role. Japanese industry is prepared to exploit superconductor technology. They dominate the world electronics market and are formidable competitors in power generators, motors, machine tools, and broadcast equipment. Other Pacific-rim nations, such as Korea, will also be prepared to challenge in the race for commercialization.

The U.S. will need to examine public policy and industrial strategy to compete. The current business climate, driven largely by the federal deficit, discourages risk and investment. Antitrust laws discourage cooperation and coordination among private companies. Patent laws do not protect us from easy foreign exploitation. Private enterprise must strive for a longer term investment strategy that includes greater capital investment. Private corporations in the U.S. must recognize the international nature of competition and revise their business strategies accordingly. They are often competing against an entire nation, not just another corporation. Our government must also recognize this and adjust its policies accordingly.

Private enterprise must once again emphasize the importance of product design, engineering, manufacturing technology, and quality in production. Universities have already begun to reemphasize the education and training of engineers.

The U.S. government is a strong supporter of science and technology. Basic science is supported at our universities, creating a symbiotic relationship between research and education that has served this nation well. Support for technology has been strongest in defense and space. Since the U.S. depends critically on new technology for defense and civilian applications, it is imperative that we get the greatest benefit from our federal investment in science and technology.

V. THE ROLE OF THE FEDERAL GOVERNMENT

The federal government must play a number of roles in supporting science and technology. It is the customer in the defense arena. It acts on behalf of our national welfare in areas such as general research, health, and environment. It plays a special role in areas such as space and energy where the combined role of individual companies may not suffice to protect our national interest. Recently, attention has focused on the appropriate federal role in enhancing the economic competitiveness of U.S. private enterprise.

Federal funding for basic research in all of these areas enjoys widespread public support. However, federal support for applied (targeted) research and exploratory development is much more controversial.

In the defense area (which in FY1986 comprised almost 73% of the federal R&D budget), the government has a clear obligation to support applied research and development because it is the customer. In agriculture, health, and aeronautics there is also a long history of federal support and success in applied research. In the energy area, the federal support for applied research and development has engendered considerable debate. The debate over federal support for applied research and development for other private enterprises has been even more rancorous.

The Kennedy, Nixon, and Carter administrations proposed ambitious federal programs to enhance our technological enterprise. However, programs such as the Civilian Industrial Technology Program (Kennedy), the New Technological Opportunities Program (Nixon), the NSF Research Applied to National Needs (Nixon), the Cooperative Generic Technology Program (Carter), and the Cooperative Automotive Research Program (Carter) did not succeed.[2]

However, the decline in the competitiveness of U.S. industry and the ensuing foreign trade imbalance warrant another look at federal policy. The Reagan administration and Congress are addressing the issue of economic competitiveness. The NSF initiative of Engineering Research Centers will help to emphasize engineering education and bring closer ties of universities to industry. In addition, NSF's current initiative of new Science and Technology Centers should further strengthen that relationship.

I believe that federal support of applied research for economic competitiveness should also be reexamined. The current Steel Initiative, which struggled through a difficult start and is now managed by the Office of Industrial Programs in DOE, is such an attempt. The more global federal role in applied research was recently examined at a workshop sponsored by the National Academy of Sciences' Committee on Science, Engineering, and Public Policy (COSEPUP).[2] The participants recommended the following guidelines for forming applied research initiatives to make them more palatable politically and more effective technically:

- "Define goals modestly.
- Tailor the program to fit the structure of the target industry.
- Match the needs of users and the capabilities of research institutions.
- Emphasize generic research, leaving product design and commercialization to the private sector."

They also observed that "the analysis of federal policies in relation to applied or targeted research disclosed several realities:

- Research cannot be divided easily into separate stages.
- The crucial criterion for research with commercial applications is not its ideological correctness but its aptness for the specific industry or industries it aims to serve.
- The success of research in stimulating innovation depends on the full range of policies affecting the target industry.
- Targeted research initiatives must walk a political tightrope, balancing the promise of near-term payoffs with technical realities, ambition with the risk of failure, and dispersed benefits with project control."

I believe that this guidance should be applied to federal support for applied research.

VI. THE INNOVATION CYCLE

Donald N. Frey, Chairman of the Board, Bell & Howell Corporation,[3] defines innovation as new combinations of ideas or concepts with a need in the marketplace--leading to successful new products or services. He points out that innovation is the driver, the engine, the economic basis for business. It involves a large number of people from many disciplines. It's opportunistic and requires a special environment; in fact, a special culture.

Innovation often, but not always, requires invention. It is important to make the distinction between invention and innovation. Invention is the discovery of new ideas or concepts but does not necessarily include bringing them to the marketplace. Invention tends to lean toward science. It is much more of an individual effort than is innovation.

The U.S. today is still rich in inventions because its basic research effort is the best in the world. It, however, no longer leads the world in innovation. Let me describe what I mean by the innovation cycle. For the purpose of discussion, I will separate it into four components: research, development, manufacturing, plus marketing and distribution. It is important to note at the outset that there are no clear cut boundaries, and that the process of innovation is not sequential. There has to be considerable overlap, feedback and dialogue for success. Therefore, I call it the innovation cycle.

Basic and applied research create the knowledge pool which is crucial for a continual flow of inventions. The Packard-Bromley Report[4] recommended a significant increase in the NSF research budget over the next five years to keep the U.S. on top in basic research. Basic research should remain unstructured, but carefully watched, and of unquestionable excellence.

Applied research tends to be more focused or targeted. It is a vital, creative part of research in universities, national laboratories, and industry. Many of our basic technologies have emerged from applied research. These include the transistor, lasers, nuclear magnetic resonance imaging, and recombinant DNA technology. Basic and applied research represent a continuum and provide an indispensable technology base for technology development.

The second component is development and consists of exploratory and advanced (or product) development. In exploratory development, research becomes even more focused, typically on techniques and technologies. It involves research and development on enabling technologies but does not necessarily have the end product clearly in sight. It is functionally distinct from basic research in that milestones, timetables, and specific goals are much more appropriate than in basic research. Advanced (or product) development is specifically tied to a product, service, or a system. By this stage, the technology should be in hand and the application clear.

For innovation to succeed, we must also strive for excellence in the other two components which are (i) manufacturing and (ii) marketing and distribution. Much of the Japanese success in the world consumer markets stems from progress in these areas. Their emphasis on quality, product engineering, systems engineering, process control, automation, etc., has paid off. These activities have earned a significantly greater prestige in Japan than in the U.S., thereby attracting some of their best talent. In addition, there are many political, social, and economic factors that influence the business climate and the innovation cycle.

In the U.S. there has been a strong tendency to describe the process of turning research ideas into products or services in terms of technology transfer. I believe this fosters an attitude that one can disconnect the research and development components from the other two in the innovation cycle. We must recognize that innovation is an interactive process (in fact, it is an experimental one that often will fail). We cannot expect to have one organization store their ideas (inventions) in a cupboard and have another come along and pick them off the shelf for commercialization.

We need both the push of innovative technology and the pull of the marketplace. We need an appreciation for the market and for manufacturing during research and development. Above all, it takes teamwork. The innovation process must be managed from the research phase all the way to the marketplace. Each step should provide feedback to the other steps. For example, problems in manufacturing should become input for research and development efforts. Lessons from marketing and service should feed back to new product design.

Today there are very few organizations in the U.S. that can claim to have the entire innovation cycle in one organization (or at least under one management). The AT&T Bell Laboratories are the best and most successful example. Their record of innovation speaks for itself.

A much less known example is that of the two DOE nuclear weapons design laboratories, the Los Alamos National Laboratory and the Lawrence Livermore National Laboratory. They have a wide range of responsibility from basic science to the design and retirement of nuclear warheads. Their responsibility in basic research is greater than most industrial or other applied science laboratories because universities do not have the interest or facilities to study some of the exotic conditions that exist in nuclear explosions. Similarly, the applied research demands are also very stringent. For instance, the enormous complexity of weapons behavior (and the difficulty of simulating nuclear detonation conditions in the laboratory) drove the development of large-scale computing and the development of supercomputers.

Exploratory development and scientific testing at the laboratories are important to the nuclear weapons science and technology base. Product development of the nuclear components is limited by U.S. statutes to the two design laboratories. Nuclear testing is conducted by the laboratories at the Nevada Test Site. Manufacturing is carried out by the DOE integrated contractors, and the laboratories have extensive (daily) interaction with these contractors. They interact on the producibility of the designs, process development, specifications for fabrication and inspection, and quality control.

The interaction with the customer (which is the military) is extensive, beginning with concept feasibility and ending with warhead retirement. The laboratories retain responsibility for the safety, security, testing, and servicing of the warheads, which means the customer interaction is frequent and continuous.

As a result of the laboratories' roles in nuclear weapons, they have been able to maintain first-rate scientific institutions with concurrent capabilities in the entire innovation cycle. They have successfully demonstrated the ability of translating research into products. They are able to field teams of scientists and engineers to solve large, complex problems. In other words, they have the unique environment that is required for innovation.

VII. A ROLE FOR DOE NATIONAL LABORATORIES

The U.S. supports over 700 federal laboratories. Of these, there is only a handful besides the DOE national laboratories that has a major scientific mission. The DOE has 36 laboratories; 9 of them are multiprogram national laboratories,* and 9 others are major single-program laboratories.[5] The major missions at the multiprogram national laboratories are defense, energy, and general science.

The DOE national laboratories can play a significant role in research and development to enhance the nation's economic competitiveness. The weapons laboratories, as indicated above, have an environment that is conducive to technology development as well as research. The other DOE national laboratories have considerable technology capabilities because of their energy missions. Most of the DOE national laboratories were involved with research and development of superconducting materials long before the recent discoveries. In fact, it is my opinion that their combined talents in superconductivity are unmatched anywhere. The time is right to exploit that resource and optimize its benefit to the nation. The national laboratories can contribute in two ways: (i) basic research and (ii) exploratory R&D (combination of applied research and exploratory development).

A. Basic Research

The U.S. funding agencies have moved aggressively to increase support for superconductivity research after the February, 1987, discovery. The NSF almost immediately made an additional $1.6M available to universities. Basic Energy Sciences (BES) of DOE also increased its support. Both encouraged redirection of ongoing research into this area. Both are making additional funds available in FY1988. Department of Defense sponsors are taking similar action.

It is crucial that basic research on high-temperature superconductors continues to be funded well. We cannot allow the knowledge pool to shrink. Attention must turn to gaining a fundamental understanding of the mechanism of superconductivity in the ceramic oxides. Continued emphasis must be placed on pushing towards new limits (such as higher critical temperatures, current densities, and magnetic fields) and new materials.

Universities are the greatest contributors to the basic knowledge pool for this nation's science and technology. In fact, they perform over 60 percent of all basic research in the U.S.[4] (although their share of the total R&D funding is only 9%). All of the DOE multiprogram national laboratories have strong basic research components. Two of the single-program laboratories, the Fermi National Accelerator Laboratory and the Stanford Linear Accelerator Center, have strictly a basic research mission.

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*DOE multiprogram laboratories and missions.[5] All are Government Owned and Contractor Operated (GOCO).

Defense and General Science	Energy and General Science
Lawrence Livermore National Laboratory	Argonne National Laboratory
Los Alamos National Laboratory	Brookhaven National Laboratory
Sandia National Laboratory	Lawrence Berkeley Laboratory
Idaho National Engineering Laboratory	Oak Ridge National Laboratory
	Pacific Northwest Laboratory

Basic research at DOE national laboratories complements that at universities. The laboratories concentrate more on multidisciplinary research and research associated with large, complex facilities. They operate an impressive array of national user research facilities for the scientific community. These include accelerators, reactors and spallation sources for neutron scattering, synchrotron light sources, and high-voltage electron microscopes. Their general science interest is augmented by their mission orientation in energy or defense.

Several of the laboratories enjoy the reputation of performing world-class research in superconductivity and materials science. For example, Los Alamos was instrumental in the discovery of heavy-electron superconductors that rekindled much of the theoretical interests in superconductivity before the recent high-temperature superconductor discoveries. All indications are that the heavy-electron superconductors require new theories to explain their superconductivity. However, their practical applications are limited by critical temperatures near absolute zero. Researchers at Los Alamos have published over 150 scientific papers on superconductivity in the past four years.

In private industry, only the large companies such as AT&T and IBM have the resources to contribute to the basic knowledge pool on an ongoing basis.

In the area of high-temperature superconductors, basic research right now is dynamic, exciting, highly competitive, and, most importantly, productive. It must remain flexible and able to respond quickly. Hence, it should be encouraged, well funded, and not overly regulated by the government.

B. Exploratory R&D

Applied research and exploratory development (lumped together here as exploratory R&D) are crucial to the innovation process. They are most effective when performed in conjunction with basic research. However, for successful commercialization, exploratory R&D must take the pull of the market into account very early in the process. This has been quite successful in the defense area but much less so in the commercial area. Industrial involvement and interaction is required from the start.

Exploratory R&D requires research on enabling technologies. It requires science and engineering focused on developing the technologies that form the basis for applications. It requires team work and, often, extensive facilities. It requires flexibility for rapid response and a close link to basic research. Moveover, it requires organization and management of the effort with particular attention to the interfaces with basic research on one hand and product development on the other.

The DOE national laboratories are well suited for this task, especially in the area of superconductors. In addition to their stature in the scientific community, they have significant technological experience with conventional superconductor applications. For example, Los Alamos designed the superconducting magnetic energy storage system for a demonstration of electric power conditioning on the Bonneville power line. Brookhaven National Laboratory constructed a test bed for a superconducting ac power transmission line. The Fermi National Accelerator Laboratory applied superconducting magnet technology for their Tevatron accelerator. It remains one of the largest applications of superconductors to date.

The national laboratories also have the facilities and capabilities in supporting areas such as materials science and technology and low-temperature physics. These will be required to develop the enabling technologies for the application of high-temperature superconductors. What the national laboratories do not have are the necessary tie to industry and the market pull. Without a close tie, exploratory R&D will not result in innovation and commercialization. Hence, I suggest a technology partnership between the national laboratories and industry in high-temperature superconductivity.

The NSF initiatives of Engineering Research Centers and Science and Technology Centers are also aimed at improving competitiveness by exploiting U.S. science and technology. In my opinion, these Centers will enhance the quality of engineering education and graduates. They will also bring more of a market orientation to universities. However, they will not by themselves fill the need for an exploratory R&D program, especially for high-temperature superconductors. As described above, the DOE national laboratories fit this need extremely well, and they would be able to respond to the challenge immediately.

VIII. AN INITIATIVE FOR EXPLORATORY R&D CENTERS

The U.S. should designate Exploratory R&D Centers at appropriate DOE national laboratories to set up technology partnerships with industry to identify and exploit the most promising enabling technologies and potential applications for high-temperature superconductors. Prerequisites for creating such centers should include: (i) demonstrated expertise in superconductivity research and other relevant technologies and (ii) a proven record of performance in exploratory R&D (including people and facilities, the ability to field R&D teams, and to coordinate R&D goals.)

Industry would be encouraged to participate at the inception, first by providing program guidance and later through cooperative R&D and as a funding source. The centers would perform R&D in:

(i) Generic, enabling technologies that are pervasive to many potential applications. These efforts are most appropriately funded by the federal government.

(ii) More specific enabling technologies that should be cost shared between government and industry, either through industry consortia or individual companies.

(iii) Very specific enabling technologies or help with occasional advanced development with full cost recovery from industry. (Naturally, this would result in exclusive intellectual property rights for industry).

The intellectual property rights of the cost-shared R&D will need to be worked out between government and industry. In his recent initiative on economic competitiveness,[6] the President made it quite clear that he wanted to enhance the transfer of intellectual property rights from the government to private enterprise.

The Exploratory R&D Centers would offer great opportunities to private industry, especially for small and medium-sized companies. The laboratories would provide staff with deep scientific foundations in the physics of superconductivity and other related technologies. They also have many of the facilities required for the synthesis, processing, and characterization of the new superconductors. This would allow industry to collaborate with laboratory researchers or try out some of their own ideas without major capital investments and in an environment that is very knowledgeable of what other scientific research is going on in the world. It would also provide almost immediate response which is crucial in this fast moving field.

These benefits may also be very attractive to some large companies which have traditionally not been involved in superconductivity research or applications. Large companies such as AT&T and IBM may also benefit from scientific collaboration in basic research. They most certainly could contribute in helping to guide the development of generic, enabling technologies. Regardless of size and specific interest of private industry, this initiative would help U.S. industry to capitalize on our scientific lead in superconductivity.

The Exploratory R&D Centers should be initially funded solely by the federal government through the DOE. To make a difference, I would propose six to eight centers funded at approximately $5M each per year for a period of five years. For the first few years an additional sum of ~$2M each per year should be allocated for capital equipment and construction needs. The center funds should be in addition to, and separate from, basic research funding from DOE/BES. It is important that basic research be encouraged and funded well at universities and the national laboratories.

Industry and DoD funding should be encouraged, especially for the more specific exploratory R&D as it pertains to their interests.

There should be some central oversight of the centers. It should involve the government (DOE) to ensure that the initiative retains a sufficiently global, long-term outlook and private enterprise to bring about a market orientation that will truly help U.S. competitiveness. Perhaps a single governing board comprised of government, industry, and university leaders should be appointed to oversee and guide the program. Private industry has shown considerable sentiment for some overall coordination of high-temperature superconductor R&D because of the intense competition that we face internationally.

IX. THE NEED FOR EXPLORATORY R&D ON HIGH-TEMPERATURE SUPERCONDUCTORS

It is important to emphasize the amount and difficulty of effort that will be required to turn the scientific breakthrough in superconductivity into commercial applications. The need for a massive effort in exploratory R&D (which this initiative will partially fulfill) cannot be overstated. While the search for higher temperature superconductors continues feverishly at most research institutions in the country, we must begin now to develop those enabling technologies that are required for commercialization because the prospects of working at liquid nitrogen temperatures are already sufficiently attractive to exploit current materials. If superconducting transition temperatures of new materials are raised to room temperature, we would enjoy an additional, enormous benefit. However, the exploratory R&D for liquid-nitrogen applications would not be in vain.

Much of the R&D required to exploit the new superconductors falls within the realm of materials science and technology. The DOE national laboratories have very strong programs in materials science and technology because of the pervasive importance of materials in energy and defense applications. In addition, DOE/BES has developed the nation's most sophisticated, advanced materials characterization facilities (with many of them being operated as national user facilities) at its national laboratories. The laboratories are in a unique position to contribute to materials development and characterization.

The new superconductors are ceramic oxides. To commercialize these materials we will need to fabricate them into useful shapes and optimize the critical properties so that they can carry large currents, function in high magnetic fields, or function in radio-frequency or microwave environments, or various combinations of the above.

Ceramics are typically very brittle (and hence unforgiving to mechanical abuse) and difficult to synthesize and process. Reproducibility of properties has been a chronic problem for ceramics. The Japanese targeted ceramics processing as a national technology priority about five years ago. The U.S. had also increased its emphasis on ceramics research, but I believe that the Japanese have a clear edge in the technology. They are in an excellent position to capitalize on their ceramics effort to exploit the new ceramic oxide superconductors.

We should identify a number of generic areas for exploratory R&D. For the purpose of this discussion, I will separate them into five categories:

(1) Bulk synthesis and processing
(2) Thin film and coatings synthesis and processing
(3) Characterization of the microstructure
(4) Physical properties
(5) Chemical, thermodynamic, and mechanical properties.

I will give only a very brief indication of the importance of each. Ceramic synthesis of bulk products typically begins with powder synthesis. Much is to be learned about producing powders of proper size, chemistry, surface area, surface activity, etc., to facilitate subsequent consolidation into dense products. Powder compaction, densification, sintering and subsequent shaping or forming will all present significant challenges. At Los Alamos we are currently pursuing some novel techniques of powder precipitation and drying, followed by hot pressing for consolidation. For a number of industrial applications, one will need to produce miles of wire or tape which will be most difficult to produce from these ceramics.

Electronic applications and superconducting radio-frequency cavities will depend on thin film and coating technologies. A variety of vapor deposition techniques such as evaporation, sputtering, chemical vapor deposition, molecular beam epitaxy, or plasma spraying hold promise. Much expertise exists in the semiconductor community, although work on the new superconductors is in its infancy.

The microstructure (crystal structure, crystal phase, orientation of crystals, defects, etc.) strongly influences the desirable properties and depends critically on the synthesis and processing. Initial indications are that the structure of the superconducting oxides is very directional (anisotropic) and that superconductivity depends critically on the specific crystal structure. From previous experience we also know that grain boundaries and second-phase particles or impurities play a major role in flux pinning required for high-magnetic field applications. Sorting out the influence of processing on microstructure and the subsequent effect of microstructure on properties will be a major undertaking.

The physical properties such as magnetic and electric properties are, of course, most important since they are the basis for the interest in these materials. These properties plus thermal properties such as heat capacity and thermal conductivity will need to be measured and optimized.

Chemical and thermodynamic properties are likewise very important. Research to date indicates that chemical composition (especially oxygen content and crystallographic position) is critically important for high-temperature superconductivity. The dependence of oxygen content on processing is still very puzzling. Moreover, the oxygen composition appears not to be very stable with time. The mechanical properties are important in mechanical processing and in any structural application where there are applied loads. The new superconductors offer the possibility of sufficiently high magnetic fields that the strength of the materials may become the limiting factor.

The requirements that I just briefly outlined appear overwhelming. Yet, they are typical of a major development of new engineering materials. The underscore the need for additional basic research to gain a better fundamental understanding on one hand and the urgency to begin an exploratory R&D program on the other. The Exploratory R&D Centers initiative can begin to develop the processing-microstructure-property relationship in these materials. Industry can link these developments to potential products.

X. SUMMARY

The U.S. is in the midst of one of the most exciting scientific discoveries of this century. The basic research community is responding splendidly in pushing the limits of superconductivity. In a period of nine months, our researchers have provided us with a quantum leap in capability.

The race to commercialize these new materials is on, and potential applications are almost without limit. The U.S. will face unprecedented international competition, and the Japanese appear particularly well positioned to win this race. The U.S. will have to marshal its resources to compete. It needs to develop a partnership among universities, federal laboratories, and private industry. Universities have begun to team with industry while some of the large industrial companies like AT&T and IBM are competing effectively. But it will take more to make the mainstream of U.S. industry competitive.

Therefore, I have proposed an initiative to develop an industry-DOE national laboratory partnership by establishing Exploratory R&D Centers at these laboratories. The centers will concentrate on the R&D for enabling technologies required to commercialize high-temperature superconductors. This initiative will in part help U.S. industry to be competitive in this new and exciting field. I believe that it will succeed where other attempts to increase competitiveness with federal stimulus have failed because the DOE national laboratories are in an exceptionally good position to contribute immediately and because industry is encouraged to participate fully at the outset.

1. Dale Russakoff; "Two Different Cadences in the Superconductor Race," quoting Frank Press; The Washington Post; May 20, 1987.

2. Kevin Kinneran; "The Federal Role in Research and Development, Report of a Workshop;" National Academy Press; Washington, D.C.; 1986.

3. R. A. Valentine, ed.; "Managing for Innovation;" Donald N. Frey; Industry, Innovation, and Technology Transfer, Lectures delivered at the Director's Special Colloquium; Argonne National Laboratory; April 23, 1985.

4. David Packard and D. Allen Bromley; "A Renewed Partnership," A Report of the White House Science Council Panel on the Health of U.S. Colleges and Universities to the Office of Science and Technology Policy; February, 1986.

5. "Technology '86;" U.S. Department of Energy Office of Energy Research Technology Transfer Program Annual Report; DOE/ER-0192/2; January, 1987.

6. Office of the White House Press Secretary; "Statement by the President;" Los Angeles, California; April 10, 1987.

Senator **Ford**. Thank you, Dr. Hecker. I have a very important meeting to attend shortly, and under the two distinguished Senators from New Mexico, this committee will be in good hands.

And Dr. Finnemore, I am going to leave with this question. In reading your statement, you have an excellent sense of humor.

How are the Presidential primaries going to turn out next year so I can get out front?

You do not have to answer that. But I thought your analogy about the football player, that he might have to pass the university entrance exam, indicated that you did have a good sense of humor.

So I will turn it over to the distinguished Senator from New Mexico, and I do thank you all.

We have two more witnesses.

Senator **Domenici** [presiding]. I don't have a lot of questions. I am going to yield rather quickly to Senator Bingaman, because we are running late.

But let me indicate to the panel that, first, specifically to you Dr. Schriesheim, I think you have analyzed this bill in its specificity as to exactly how we ought to do this.

Obviously, not only this committee, but this committee and some House committees and executive people are going to decide. But I think you have really captured the essence when you used two words, cultural change.

And I have not been heretofore in my own analysis of the failure to utilize knowledge and research adequately in our country anywhere near as direct. It has always taken me an awful lot of sentences to come up with that simple expression.

And I compliment you for it, and also for your statement that it will not occur overnight. But then your very positive analysis that it must occur, or we will not maintain the kind of competitiveness, and will not use the knowledge basis appropriately is right on target.

I am absolutely convinced that is the case. Whether we can, by legislation, encourage the new arrangements which maximize the current knowledge base and research is speculative at this point, and may depend on leadership as compared with legislation.

I am beginning to have some concern about that also. But I am firmly convinced that we are not making adequate use of the combined knowledge base in this country, because we have compartmentalized it.

And then, Dr. Hecker, you made speech making on the subject very easy when you coined a phrase. I was trying to say this, and as you might gather, I had difficulty with the previous panel. You summarized it by saying, user friendly.

I am absolutely convinced that cultural change and user friendliness, with reference to the labs, is the real key in the areas that we are trying to address in this legislation.

We really are trying to affect that in the three areas that the bill covers. Whether we can or not, I don't know.

So I am going to start with just one basic question to each of you. If you set this legislation aside, based on your experience, if you had one thing, one item, one explanation, of how to best utilize these labs, to effect this cultural change and make them user friendly and effective, what would that one thing be?

Dr. **Schriesheim**. That is a good question.

Senator **Domenici**. Let me tell you what bothers me. I am wondering if, if we take a national laboratory that has been somewhat restricted in its activities, and an industry that has been somewhat skeptical, so that we have a different culture, and we don't have a user friendliness.

And then we say to the director of that lab, with this new legislation and a little bit of money, we are saying to you, do something you have not necessarily been doing, and the outside world hasn't been meshing with you. I am wondering if there is some ingredient in that is basic without which it won't work.

I do not know what that is. But I have great empathy with Dr. Hecker. He is charged with trying to do it. And he is out talking to the industry, and asking you all in the labs about it. But I wonder if there is some one thing that we have to look for in there that might be the most important in making that work.

Dr. **Schriesheim**. Senator, I always look at people, the leadership of an organization, the individuals within the organization, with the appropriate leadership, with the appropriate desire on the part of key people in the national lab system, key people here and in the agencies.

There is every reason to believe that these kinds of relationships will be forged, but not overnight. We have gone through this with a number of initiatives that I mentioned, and I am sure Dr. Hecker has others he can mention, the steel initiative, the biotechnology initiative.

So with the desire, with the appropriate people, and with the appropriate legislation, all of those coming together, that would be where I would look.

Now we have what I consider to be certain irresponsible statements, I must say made by some leaders of industry, about the difficulty of coupling into the national labs for example, and you cannot do it if you don't try.

And that is what I mean when I talk about leadership. If there is a desire to do this, I believe it will be done. And the first item to look at is who is doing it, at least that is where I would look.

I must say, I do not have a simple formula.

Senator **Domenici**. Dr. Forsyth.

Dr. **Forsyth**. I would like to draw on an example from Brookhaven that has worked very well. And that is the industrial participation in the national synchroton light source that has a great deal of interest.

The X-ray lithography that Congressman Hochbrueckner referred to has done that. And when I turned over your question in my mind, I asked myself what was the one thing—it is difficult to say one, but in fact, I think having a facility the industry wants to use, and then providing the facilities they need to use it.

And that doesn't just mean physical plant, but patents are very important, and protection against antitrust legislation, and in fact, the physical plant, enough money to give them an office.

That is one of our problems at Brookhaven. They live in trailers and things.

You know if we can give them a proper center, and they can seem permanent, that, I think, would help to create an atmosphere that this is a change for the better and for a long time.

Senator **DOMENICI**. Dr. Finnemore.

Dr. **FINNEMORE**. There's a fairly long culture in the university of not making money, and to be innovative and to make money and to mix it with Federal support for research.

We are changing that culture a little bit. We are encouraging all the faculty to go out and start companies and do all of those things. And many people need an insurance policy.

The first five or six who do it wrong, we should know ahead of time, so that you've got risk taking, so that the first half a dozen people who make a bad mistake, you do not string them up by the ears, but you say, just don't do it again.

Senator **DOMENICI**. Dr. Hecker.

Dr. **HECKER**. If there was one thing we could change, I think I would look at the DOE labs and see where we have been successful in the area of technology transfer.

And that is in the defense arena. And the reason we have been successful is because technology development and transfer is actually part of our charter, part of our primary activity.

I think the one thing that we could change to make technology transfer more successful in the private arena is also to make it more of a primary part of the charter of the Department of Energy.

I think to date the technology transfer has been more of a secondary or spinoff activity because of our primary charters. And yet, if you the Congress, and if American industry expects us to be more effective in transferring technology, then it should be more of the charter of the department, and therefore, be ingrained in the charters of the laboratories.

I think that would help to effect a cultural change on the nondefense end of the Department of Energy laboratories.

Senator **DOMENICI**. Well, I want to thank all of you for your prepared remarks and for your summaries. You can rest assured, subject only to whether our distinguished chairman wants to move ahead rapidly or not, and it is clearly up to him, but if he does, we will surely try to move ahead in this area.

That doesn't mean we will stop getting your advice. And we hope that in the next month or so we can complete something in this area.

In the meantime, as we move through it, we will ask our staff to stay in close contact with reference to any changes we make so you can give us your opinion as to whether they are on the plus side.

There will have to be some give and take in order to satisfy the Department of Energy. You can tell that already, based on their comments and my opening remarks.

But I want to thank all of you very much, and we will move ahead. And we wish you every success.

Our last panel is Mr. Floyd Culler, President of Electric Power in Palo Alto, and Dr. John Rowell, Assistant Vice President of Solid State Science and Technology Research, Bell Communications.

Mr. Gene Mannella, as I understand it, you will be introducing Mr. Floyd Culler, is that correct?

STATEMENT OF FLOYD L. CULLER, PRESIDENT, ELECTRIC POWER RESEARCH INSTITUTE, AS PRESENTED BY GENE MANNELLA, DIRECTOR, WASHINGTON OFFICE OF ELECTRIC POWER RESEARCH INSTITUTE

Mr. MANNELLA. I will be giving a summary of his testimony, Senator.

Senator DOMENICI. Fine. And you want to proceed in lieu of Mr. Culler, is that correct?

Mr. MANNELLA. That's correct.

Senator DOMENICI. Please proceed.

Mr. MANNELLA. Thank you. I want to thank you for the opportunity of testifying on behalf of the Electric Power Research Institute today.

I would ask that the brief written comments that we submitted be included in the record, and I will give a very brief overview of them here today.

Also I would like to mention that because of some complications on our part having to do with vacations and such, we were not able to prepare an extensive written record, and we hope to submit one to the committee before the record closes, sometime within the next 10 days to two weeks, if that is appropriate.

Senator DOMENICI. That is satisfactory.

Mr. MANNELLA. Thank you.

Senator Domenici, let me briefly just remind you and the people present of the origins and missions of the Electric Power Research Institute, or EPRI.

We were established by the electric utility industry in 1972 to conduct a broad research and development program for the entire electric utility industry and its ratepayers.

EPRI's main mission is to develop new and improved technologies for electric power production, delivery and use, and to help accelerate their availability and insuring an adequate supply of economic, reliable and environmentally acceptable electricity.

EPRI is supported by voluntary contributions from investor owned, government owned, and cooperatively owned electric utilities across the Nation, and we have an annual budget of approximately $325 million to carry out this mission.

I would like to turn very quickly to S. 1480 and to make the following specific comments. And incidentally, I hope I can very briefly address Title III, which is the subject of the hearing on Thursday, but I do have one comment that I would like to make very quickly here.

With regard to the proposed legislation, EPRI supports the general purpose of the bill, and applauds the effort to involve the great national laboratories of DOE, and a broader participation and cooperation with industry and the universities.

We think that the three disciplines that are cited in the bill are very appropriate: superconductivty, mapping the human genome, and semiconductor R&D are nationally significant.

With regard to Title I on superconductivity, we endorse the formation of the interdisciplinary council to advise the Secretary of Energy on the planning, execution and handling of the intellectual properties, exchange of information, and the development of new technology.

We would like to suggest several points to strengthen the role of that council, namely, that it should suggest which applications have priority because of their importance to the economy.

And furthermore, since the length of time that we are talking about in the development and commercialization of this technology is long, that some thought be given to the composition in the council membership so that it can provide continuity of purpose over a period of years, and perhaps over administrations.

We feel that opening the national laboratories to direct cooperation with industry and universities is a very important step, and we think that formation of consortia is a very desirable approach, which provides a variety of experiences and potential means of introduction of new technology.

We would like to point out that we have been somewhat active in this regard. For example, we have recently established a center for power electronics development, which involves the Tennessee Valley Authority, the Oak Ridge National Laboratory, and the University of Tennessee.

And we have discussions underway with other national labs on superconductivity.

One of the key elements that we feel may be lacking in the proposed legislation in producing internationally competitive new technology from the innovations in science is the ability to fund demonstrations on a significant industrial scale.

You have heard mention several times today that one of the possible applications may be superconducting magnetic energy storage.

This is one of the applications that would certainly be of interest to the electric utility industry, but a utility sized demonstration of that application would be very expensive.

And the consortia should have the ability to proceed into that phase if it continues to look attractive.

And as I mentioned, I would like to make one quick comment relative to Title III on the semiconductor section. We would suggest broadening the scope and the participants in the development of the semiconductors.

The program as described is for microelectronics, principally, and ignores the field of macroelectronics using semiconductors.

Power semiconductors for use as motor drive speed controls, for power line switching, and other applications in the utility industry is a major new field we are very excited about.

And we have established a center for power electronics, as I mentioned to you just a few minutes ago, as a cooperative effort which we would like to bring to your attention.

This concludes my brief remarks, Senator, and I would be happy any questions that you might have.

[The prepared statement of Mr. Culler follows:]

Testimony of Floyd L. Culler
President
Electric Power Research Institute

Senate Bill 1480
Subcommittee on Energy Research and Development

September 15, 1987

Presented by

Dr. Gene G. Mannella
Director
EPRI Washington Office

Testimony on S. 1480
"Department of Energy National Laboratory Cooperative Research Act"

Mr. Chairman:

I am Gene Mannella, Direcotr of the Washington Office of the Electric Power Research Institute. I am presenting a brief summary of several of the important points in the prepared testimony on S. 1480 on behalf of Mr. Floyd L. Culler, President of the Electric Power Research Institute. I ask that the complete testimony be included in the record of these hearings.

The Electric Power Research Institute does research and development for the electric utilities of the United States. It is the first large, successful, privately funded R&D collective in the U.S., having been founded in 1972. Its programs include a broad spectrum of work in the energy field, and are coordinated with many federal agencies, principal among them being the Department of Energy. Electric utilities of all classes; i.e., investor owned, federal energy authorities, municipal public power utilities and the rural electric companies make up the EPRI membership.

Mr. Culler, prior to his becoming President of EPRI, was employed for 35 years at Oak Ridge National Laboratory, where he served in many positions of responsibility, including Deputy Laboratory Director. Thus, he is very well acquainted with both work in DOE's national laboratories and in the industrial sector. He serves on technical advisory committees in several universities as well, and is exposed to university research.

The few comments which I will make concern Title I and Title III of the proposed bill, not Title I alone because coordinated R&D in semiconductors is of great importance to the electric utilities and to EPRI.

Because of limited time for presentation, I will present a very brief statement with back-up discussion. These are just on what we consider to be the most important issues.

1. I agree and support the general purposes of the bill and applaud the effort to involve the great national laboratories of the DOE in a broader participation and cooperation with industry and the universities.

2. The three disciplines of projects selected, superconductivity, mapping the human genome and semiconductor R&D are very important areas for this coordinated R&D thrust.

3. For Title I Superconductivity, I endorse the formation of an Interdiciplinary Council to advise the Secretary of Energy on the planning, execution, handling of intellectual properties, exchange of information and on the development of technology which the new superconductors may make possible. I have two points in addition:

    a. The Council should also be asked to suggest which applications should have priority because of their importance to the economy.

    b. Since the length of time required to understand these materials and to produce important new systems based on their properties is long, extending well beyond the political tenure of most political appointees, the Council membership should be set up so that it can provide continuity of purpose and plan.

4. The opening of the laboratories to direct, rather than indirect via Washington, cooperation with industry and universities is an important advance both for industry and for the labs.

5. The formation of consortia is a very desirable approach which provides a variety of experiences and a potential means of introduction of new technology. The basic idea of consortia is an important element in EPRI programs. We have established three cooperative R&D centers involving many firms and organizations. One of these is the Center for Power Electronics Development involving TVA, ORNL and the University of Tennessee. Similarly, we are already involved with ORNL, Argonne, Brookhaven, and others, to a lesser degree, on superconductivity.

6. The bill in its several sections does not include attention to a very key element in producing internationally competitive new technology from the innovations of science, that of demonstrations of significant and industrial scale. Japan's MITI underwrites the proof of principle, proof of economics, proof of safety, proof of market acceptability, and proof of quality projects. They are high risk, involving more risk than most private companies can afford. An example for superconductivity might well be the cost of demonstration projects for superconducting electrical storage.

7. In considering the Title III semiconductor section, an excellent case is made for broadening the scope and the participants in the development of semiconductors, most of which we heartily endorse. But the program as described is for microelectronics principally and ignores completely the field of macroelectronics using

semiconductors. Power semiconductors for use as motor drive speed controls for power line switching, for controls, for frequency and voltage control, for power transients, etc., is a major new field in which the electric utilities have great interest around the world. It is a field where we have a great opportunity for technical leadership and industrial preeminence. At EPRI, as I have already mentioned, we have established a Center for Power Electronics, a cooperative effort similar to the proposed organizations in the Bill.

There are many additional points of importance which are contained in our full testimony which deserve attention. For today and the opportunity to appear in general support of the important proposals contained in the Bill, we thank you.

Senator DOMENICI. Thank you very much, Mr. Mannella.

Dr. Rowell?

STATEMENT OF DR. J.M. ROWELL, ASSISTANT VICE PRESIDENT, SOLID STATE SCIENCE AND TECHNOLOGY RESEARCH, BELL COMMUNICATIONS RESEARCH

Dr. ROWELL. Thank you. I believe I was asked to testify here as a representative of industrial research. And let me say that the reactions I have going to give you are certainly personal reactions, not reactions from the communications industry by any means.

Let me first summarize my reactions to proposals of the bill. First, I support the suggestion, the role of the Federal laboratories in transferring technology from the universities of the United States to industry, needs examination, definition and enhancement.

Secondly, I agree that for this to be effective, industrial input into the programs of the proposed national laboratory centers is required, both during the formative stage, and in an ongoing influential manner.

Third, I suggest that other fields of science and technology not be neglected at a time when superconductivity is distracting the attention of our policymakers.

Fourth, while definition of the role of the Federal labs in the creation of these centers, might enhance the capability of U.S. industry to compete in world markets, both the short and long term competitiveness of U.S. industry remains the responsibility of industry itself.

Let me now expand on these points in order a little bit.

It is my view that in fields I am familiar with, largely solid state physics and materials research, the research strength of the United States resides in its universities. They are now our national resource, despite their real problems, for example, underfunding and lack of instrumentation.

They continue to replenish the knowledge base on which future technologies will be built.

The question, of course, is who will create these technologies, and which country will benefit from them? Today, the evidence is that this will not be the United States.

Given that this knowledge resides in the universities and should be utilized by industry, there are three primary routes by which this transfer of information can occur.

You will note I use the phrase, information transfer, rather than technology transfer, in that I do not believe it is the university's responsibility to produce technology.

The first route is to have the universities reach out toward industry, and the engineering research centers created by the NSF where, as an example, our new attempt to do this.

The second is for industry to have research organizations of their own which are healthy enough to access this knowledge base for the long term benefit of their owner companies.

The third is to have the Federal laboratories focus this information, develop underlying generic technologies, and transfer these in a form that industry finds more valuable, that is more usable in the short term.

For the United States to receive full value from its investment in basic research in its universities, that value being ultimately represented as new technology with which its industry can compete, I feel that all three of these routes of technology transfer must be alive and well.

This bill aims to specifically address the role of the Federal labs. But this role will be complementary to the other two routes of information flow, and should not be considered as a replacement for them.

Turning now to superconductivity in particular, I can envision two different ways in which the centers proposed by the bill could be structured.

The first would be for each center to emphasize an underlying science problem, for example, synthesis, physical properties, characterization, processing, thin films, and conductor fabrication.

This would create an overlap with university groups having similar interests.

The second proposal would be to have each of the centers and the Federal labs emphasize from the outset one of the industries that would be impacted by superconductivity.

For example, energy, transportation, computing, communications, and medicine.

In this case, the overlap of these programs is more naturally with industry, and who will therefore better appreciate their function in the formation of research consortia with these industries is then easier to imagine.

However these centers are structured, their success as measured by their impact on industry cannot be taken for granted. Our Federal labs are not at present surrounded by high technology industrial parks.

Even worse, in some cases technology developed in these laboratories has been used to compete with and to discourage U.S. industries, whereas in other countries it has been used to create industrial strength.

There are even examples of this in superconductivity. Thus I come to my second topic: How can the impact of these Federal laboratory centers on industry be optimized?

The simple step, given that it is generally agreed that technology transfer occurs by the exchange of people, is to require in the structure of the centers the exchange of university and industry personnel into the centers, and that the employees from the centers spend part of their time assigned to universities and industry.

As someone who has been in an industrial laboratory for more than 25 years, it is my observation that we have benefited greatly from extended, say six months to one year, visits from university professors, but that such visit from Federal laboratory scientists have been extremely rare.

I personally favor the movement of personnel from the Federal laboratory centers to industry and universities rather than the reverse.

While I see value in movement in both directions, I feel strongly that only by being exposed to industrial research or to development in manufacturing can the employees from the centers gain a first-hand appreciation of the realities and constraints of the marketplace.

In addition to the movement of people, the success of these centers will also depend on involving industry leaders at a very early stage, and in defining and planning the research programs.

There is no point in these centers developing technology that no existing industry is willing to manufacture, or around which venture capital will not create new industry.

The most rigid way of ensuring industrial support for the output of the centers would be to insist that all center programs be jointly funded in advance by both industry and the Federal government.

But given the present short-sightedness of U.S. industry, its obsession with this year's financial reports and lack of appreciation of long term value of research, such a requirement might result in no centers being formed at all.

However, some measurement of the enthusiasm of industry for each program of the centers must be obtained, and industry leaders should be involved in the direction of the centers in a way that ensures close coupling of the programs with the needs of their own industries.

My third point is to express concern that superconductivity, however exciting the recent breakthroughs have been, is not the only field of contents, matter and material research of technological importance.

There is ample historical evidence that these research disciplines have had an immense impact on our way of life and standard of living.

We do not have to search for spinoffs from solid state materials research. They are self evident.

I therefore strongly support the proposals of this bill in other fields such as microelectronics.

Further I would like to see the aims of this bill, namely coupling the Federal laboratories more effectively into what is primarily the civilian sector of U.S. industry extended into many other subfields of materials research.

While superconductivity has attracted our attention because of singular and sudden breakthroughs, there has been perhaps comparable advances in other fields, with the results of many years of steady progress, and therefore have gone largely unnoticed.

One example is the capability to engineer materials on the atomic scale, whether they be semiconductors for electronic devices, conducting wires so small that the wave nature of electrons or the properties of a single defect can become a dominant concern; polymers that are conducting or have unusual nonlinear optical properties; or a few atoms manipulated in a scanning, tunnelling microscope.

No one can at present predict with confidence whether these advances will eventually have a more or less important impact on technology than superconductivity.

My own view is that to date the proposed uses of the newly discovered superconductors do not promise to introduce radically new technology, although they may do so in time, for example, if room temperature superconductors are discovered.

On the other hand, there is no doubt in my mind that the information age depending on semiconductors and optical fiber will change society in profound ways.

We must take great care that while the attention of our scientists, funding agencies, and policymakers is focused on superconductivity, other equally or more important fields of science and technology do not drift gently across the oceans, both the Pacific and the Atlantic, to our competitors.

My final point needs little elaboration. It is that U.S. industrial competitiveness rests on the shoulders of U.S. industry.

There is little point in nurturing the research talents of our universities or in strengthening the capabilities of the Federal labs to transfer the fruits of these talents to the industrial sector if that industry is incapable of creating and manufacturing products that should flow from research.

Industry must have the courage to compete in the world arena of high technology in the long term. They must be encouraged to compete by supportive government policies that reward investment in the future.

By its very nature, today's research will not impact earnings during the tenure of any of today's chief executive officers.

They, as to the vision of their predecessors, who along with their competitors, believe that the gamble of research would result in long term benefits.

We must insure that the leaders of today's industry can look at the lessons of history, examine the current scientific advances in superconductivity and many other fields, and be willing to speculate that some of those advances can be turned into technology that our grandchildren will find commonplace.

[The prepared statement of Dr. Rowell follows:]

Testimony on S1480, A Bill: To improve the integration of universities and private industry into the National Laboratory system of the Department of Energy in order to speed the development of technology in areas of significant economic potential.

J. M. Rowell
Bell Communications Research
Red Bank, New Jersey

I have been asked to present comments on the above bill, in particular Title 1, which reads, "ESTABLISHMENT OF UNITED STATES INDUSTRY AND DEPARTMENT OF ENERGY LABORATORY CENTERS FOR RESEARCH ON ENABLING TECHNOLOGIES FOR HIGH-TEMPERATURE SUPERCONDUCTING APPLICATIONS".

Let me first summarize my reactions to the proposals of this bill. First, I support the suggestion that the role of the Federal Laboratories in transferring technology from the universities of the United States to industry needs examination, definition, and enhancement. Second, I agree that for this to be effective industrial input into the programs of the proposed National Laboratory Centers is required both during the formative stage and in an ongoing influential manner. Third, I suggest that other fields of science and technology not be neglected at a time when superconductivity is distracting the attention of our policy makers. Fourth, while definition of the role of the Federal Laboratories and the creation of these centers might enhance the capability of U. S. industry to compete in world markets, both the short and long term competitiveness of U. S. industry remains the responsibility of industry itself.

Let me now address these points in order.

It is my view that in fields I am familiar with, largely solid state physics and materials research, the research strength of the United States resides in its Universities. They are now our national resource. Despite their real problems, for example underfunding and lack of instrumentation, they continue to replenish the knowledge base on which future technologies will be built. The question is, of course, who will create these technologies and which country will benefit from them. Today the evidence is that this will not be the United States. Given that this knowledge resides in the universities and should be utilized by industry, there are three primary routes by which transfer of information can occur. (You will note I use the phrase "information transfer" rather than "technology transfer", in that I do not believe that it is the universities' responsibility to produce technology.) The first route is to have the universities reach out towards industry and the Engineering Research Centers created by the NSF are an example of a new attempt to do this. The second is for industry to have research organizations of their own that are healthy enough to access this knowledge base for the long term benefit of their companies. The third is to have the Federal Laboratories focus this information, develop underlying generic technologies and transfer these in a form that industry finds more valuable, i.e. more usable in the short term. For the United States to receive full value from its investment in basic research in its universities, that value being ultimately represented as new technology with which its industry can compete, I feel that all these three routes of knowledge/technology transfer must be alive and well. This bill aims to specifically address the role of the Federal Laboratories, but this role will be complimentary to the other two routes of information flow, and should not be considered as a replacement for them.

Turning now to superconductivity in particular, I can envision two different ways in which the centers proposed by this bill could be structured. The first would be for each center to emphasize an underlying science problem, for example synthesis, physical properties, characterization, processing, thin films and conductor fabrication. This would create a rather natural overlap with university groups having similar interests. A second proposal would be to have each of the centers at the Federal Laboratories emphasize from the outset one of the industries that will be impacted by superconductivity, for example, energy, transportation, computing, communications, and medicine. In this case the overlap of these programs is more naturally with industry, which will therefore better appreciate their function, and the formation of research consortia with these industries is then easier to imagine.

However these centers are structured, their success, as measured by their impact on industry, cannot be taken for granted. Our Federal Laboratories are not at present surrounded by high technology industrial parks. Even worse, in some cases technology developed in these laboratories has been used to compete with and discourage U. S. industry, whereas in other countries it has been used to create industrial strength. There are even examples of this in the field of superconductivity.

Thus I come to my second topic, how can the impact of these Federal Laboratory Centers in industry be optimized. A simple step, given that it is generally agreed that technology transfer occurs by the exchange of people, is to require in the structure of these centers the exchange of university and industry personnel into the centers, and that the employees from the centers spend part of their time assigned to universities and industry. As someone who has been in an industrial laboratory for more than 25 years, it is my observation that we have benefited greatly from extended (6 months - 1 year) visits from university professors, but that such visits from Federal Laboratory scientists have been extremely rare. I personally favor the movement of personnel from the Federal Laboratory Centers to industry and universities, rather than the reverse. While I see value in movement in both directions, I feel strongly that only by being exposed to industrial research or to development and manufacturing, can the employees from the centers gain a first hand appreciation of the realities and constraints of the marketplace.

In addition to the movement of people, the success of these centers will also depend on involving industry leaders at a very early stage in defining and planning the research programs. There is no point in the centers developing technology that no existing industry is willing to manufacture, or around which venture capital will not create new industry. The most rigid way of ensuring industrial support for the output of the centers would be to insist that all center programs be jointly funded in advance by both industry and the federal government, but given the present short sightedness of U. S. industry, its obsession with this year's financial report, and lack of appreciation of the long term value of research, such a requirement might result in no centers being formed at all. However, some measurement of the enthusiasm of industry for each program of the centers must be obtained, and industry leaders should be involved in the direction of the centers in a way which ensures close coupling of the programs with the needs of their own industries.

My third point is to express concern that superconductivity, however exciting the recent breakthroughs have been, is not the only field of condensed matter and materials research of technological importance. There is ample historical evidence that these research disciplines have had an immense impact on our way of life and standard of living. We do not have to search for spin-offs from solid state materials research, they are self evident. I therefore strongly support the proposals of this bill in other fields, such as microelectronics. Further, I would like to see the aims of this bill, namely coupling the Federal Laboratories more effectively into what is primarily the civilian sector of U. S. industry, extended into many other subfields of materials research. While superconductivity has attracted our attention because of singular and sudden breakthroughs, there have been perhaps comparable advances in other fields that are the result of many years of steady progress and have therefore gone largely unnoticed. One example is the capability to engineer materials on the atomic scale, whether they be layered semiconductors for optoelectronic devices, conducting wires so small that the wave nature of electrons or the properties of a single defect become of dominant concern, polymers that are conducting or have unusual non linear optical properties, or a few atoms manipulated in a scanning tunneling microscope. Nobody can at present predict with confidence whether these advances will eventually have a more or less important impact on technology than superconductivity. My own view is that, to-date, the proposed uses of the newly discovered superconductors do not promise to introduce radically new technology, although they may do so in time, for example, if room temperature superconductors are discovered. On the other hand, for example, there is no doubt in my mind that the information age, depending on semiconductors and optical fiber, will change society in profound ways. We must take great care that, while the attention of our scientists, funding agencies and policy makers is focussed on superconductivity, other equally or more important fields of science and technology do not drift gently across the oceans (both Pacific and Atlantic) to our competitors.

My final point needs little elaboration. It is that U. S. industrial competitiveness rests on the shoulders of U. S. industry. There is little point in nurturing the research talents of our universities, or of strengthening the capabilities of the Federal Laboratories to transfer the fruits of these talents to the industrial sector, if that industry is incapable of creating and manufacturing the products that should flow from research. Industry must have the courage to compete in the world arena of high technology in the long term, and must be encourage to compete by supportive government policies that reward investment in the future. By its very nature, today's research will not impact earnings during the tenure of any of today's Chief Executive Officers. They are heirs to the vision of their predecessors, who, along with their competitors, believed that the gamble of research would result in long term benefits. We must ensure that the leaders of today's industry can look at the lessons of history, examine the current scientific advances in superconductivity and many other fields, and be willing to speculate that some of those advances can be turned into the technology that our grandchildren will find commonplace.

Senator DOMENICI. Thank you very much.

Let me ask you, Dr. Rowell, do you think that in light of the current corporate attitude that you have expressed differently than I will of bottomlineitis, as I call it, while you would think we should have a match program right up front with industry, you are not recommending that because you are fearful it won't occur at the beginning; is that correct?

Dr. ROWELL. That's right.

Senator DOMENICI. On the other hand, do you feel that if properly structured industry will participate, even if we cannot expect our $5 million in Federal funds, that there would be $5 million from them?

Do you think we can structure a change in relationships where industry will be interested in working with these various centers?

Dr. ROWELL. Yes, I think there is ample evidence that industry is very much interested in leveraging, if you like, its investment in its own research.

The larger industrial research organizations, however big they may be, are still not big enough that they can satisfy the needs of their owner companies.

And therefore, the additional strength of other organizations I think is always viewed favorably. My impression is, at present, in most cases, certainly in our own case, we get most of that leverage by interaction with universities.

I do not know why in history it has happened that way, but it is certainly true. The number of university visitors that we have in our own lab must be 100 times greater than the number of Federal lab visitors that we have coming through.

And the reverse is probably true, that the number of visits we make to universities is many times larger than the visits we make to Federal labs.

Senator DOMENICI. And as to the latter, do you have any explanation for it, why you have far less visits with laboratories than with universities?

You say the university visits to you are far more frequent than visits from lab personnel. But then you said your visitations to universities is far in excess of those to the labs.

Dr. ROWELL. That is right.

Senator DOMENICI. Can you tell us why the latter?

Dr. ROWELL. I think to a great extent there is a feeling that is where the excitement is right now. And I think that to some extent is true in superconductivity, although some very nice work has been done in the Federal labs.

But from the point of view of our own work in superconductivity, I see a much more natural overlap right now with programs in universities, such as Stanford, than I do with the Federal labs.

Senator DOMENICI. So aside from something that is quality, you would agree with Dr. Hecker that one of the approaches has to be to make the lab—if we are going to move in this direction—is to make them more user friendly?

Dr. ROWELL. And I think particularly the thing to stress is that they should be friendly to the smaller industries.

If you look at the United States, you can take IBM and AT&T, because you take those off the list probably because they are big enough to launch the go-it-alone, and they might not be as interested in interactions with some of the Federal labs.

But you take anybody else, I think we are not of sufficient size that we can go it alone. So we strengthen ourselves, as I said, at present, by interacting with universities.

I think if they're strong, and as you say, friendly programs in the Federal labs, we would be just as glad to interact with them and have them interact with us.

Senator **Domenici**. I do not know that any members of the committee will have any additional questions, but if they do, we will submit them to you quickly, and if you could answer them within 10 days or so, we would greatly appreciate it.

I want to thank you not only for your testimony but for your patience. And I want you both to know that your testimony has been very constructive.

I would say to you, Dr. Rowell, especially your notion about the swapping of personnel, which you made a very significant part of your argument, that you ought to have the laboratory personnel move into the private sector for some period of time sufficient to get acclimated or of a frame of mind to be more understanding of the problems.

I am very impressed, and we will see how that fits into the scheme.

Dr. **Rowell**. The universities have what they call a sabbatical year. I have never convinced my management that is a great thing for us to have, although we do it informally now and again.

But maybe you ought to think about that for the Federal labs also.

Senator **Domenici**. I think we probably have more of it already than you are aware of.

And if we could put Dr. Hecker back on, he probably could explain it. But we are not going to do that.

There is an exchange of personnel, and a lot of education going on in the laboratories that people do not know about.

Universities have student programs within the labs. It is a very big country, and consequently, we do not necessarily have as much impact or recognition.

I think we are going to recess now until Thursday at 3 o'clock.

[Whereupon, at 4:50 p.m. the hearing recessed, to reconvene Thursday, September 17, 1987.]

DEPARTMENT OF ENERGY NATIONAL LABORATORY COOPERATIVE RESEARCH INITIATIVES ACT

THURSDAY, SEPTEMBER 17, 1987

U.S. SENATE,
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The subcommittee met, pursuant to notice, at 2:10 p.m., in room SD-366, Dirksen Senate Office Building, Hon. Wendell H. Ford, presiding.

OPENING STATEMENT OF HON. PETE V. DOMENICI, A U.S. SENATOR FROM THE STATE OF NEW MEXICO

Senator DOMENICI. I have been advised that we should get started. Senator Ford has sent word for me to commence the hearings, he ought to be here soon. Might I ask, Senator Evans, I am supposed to be, for part of the afternoon, at a full Appropriations Committee markup, and I may have to leave. Is it your intention to be here for part of these hearings today?

Senator EVANS. Yes. I will be pleased, Mr. Chairman, to continue on if you promise to do the right things on the Appropriations Subcommittee. [Laughter.]

Senator DOMENICI. We have gotten to the point where we do not know what doing right is. But we will at least promise you in our usual manner that we will do our very best. I think perhaps what I ought to do since the Chairman is not here is to give a little background about what brings us here and what we are trying to do. I know we are going to have some very distinguished witnesses. I do not think we are going to have a major disagreement on goals. But I tend to think what we are going to have is an agreement on goals, but, and then it's going to be very interesting when we hear what but is.

I am just hopeful that nobody concludes that what we are trying to do is to take any significant scientific turf away from any existing institution in the United States and put it in another. That is the furthest thing from our desire.

What we really would like to do is establish that the mapping of a human genome on an expedited track is a worthwhile goal, and why, and then try to establish whether or not the United States is moving in that direction or not. And if not, is there a way to do it, without infringing on the areas of expertise and the commitment that exists in existing institutions. Be it the technical expertise of the national labs, the biomedical and technical expertise of NIH, or indeed, the work of private sectors firms or universities, who may be working in conjunction with the National Institutes of Health.

I don't have any doubt in my mind that we are on a subject that is of significant importance to this country. Once the frontier of mapping the human genome is crossed that, we may be able to make great strides towards disease control and prevention. Already the mapping advances have had a powerful impact on our diagnostic capabilities, with regard to several genetically linked diseases of which I understand there are over 3,000 currently known.

Many of these diseases are caused by a single abnormality in a gene. Identification of some of these have greatly helped in the fight against such terrible diseases as cystic fibrosis, Huntington's disease, and muscular dystrophy. Many of you may know of more.

There are many diseases currently known to be linked to genetic abnormalities and almost every day scientists seem to find a genetic link to another ailment. It is our understanding that if we do not proceed in a rather expeditious manner to map the human genome, taking into consideration the targeted tasks that already exist within NIH and within our universities, that we will not have total freedom and assurance that we will be the ones to do it. Indeed, Japan may already be engaged in an effort that could lead to an expedited mapping and maybe even sequencing on their part.

It seems to some of us that since we are the leaders in all respects in this area, we ought to finish the job and make this new diagnostic tool available to the biomedical community and thus to humankind.

I have other observations in my opening remarks. I am going to ask our Chairman, who has arrived, to just make them part of the record. I would like everyone to know that the bill that is before us was introduced a long time ago. In the meantime, many negotiations have occurred with a number of the agencies that are here. We are prepared to make some significant changes in them, in the bill already, because of the discussions that have occurred between agencies of interest, universities that have interest and the private sector.

Essentially, we are trying to set up a national policy board. Who should be on it is up for discussion. The goal of the board would be to coordinate the activities and policies of the various government agencies involved in this genetic research. Relevant non-governmental institutions would be represented on the board.

Ultimately it seems, at least to me and by tener of the bill, is that we ought to, at the earliest possible date try to get the private sector involved, that is the user, and make this project and program "user friendly" by getting them onboard as early as possible in some way that is reasonable and rational to everyone. We need not favor anyone. That may not be possible, but at least that is our goal and our hope.

We know that the National Institutes of Health are America's lead agency at this point in terms of directing this endeavor and linking with our universities through their extramural program. But we also know that very special skills and talents exists elsewhere, such as in the national laboratories of the United States. Some of the technical work conducted at the labs, principally that which involves computerization and the technical aspects of gene mapping and sequencing, may be able to generate the engineering capability to complete the work more rapidly. Perhaps they will be able to do that in conjunction with others who are also involved.

So I hope no one thinks that this committee, at least I do not intend, Mr. Chairman, is trying to take anything away from anyone. We want to try to have those that are working in this area to work in a coordinated manner. Before you arrived Mr. Chairman, I said I was quite sure that every federal agency that is involved would at least open their remarks and say they favor the goals of this bill and then say the very ominous word "but," and then we will hear the discussion of why we do not have to do it, or why it is already being done and done well, or why the national labs ought to play less of role. Some will want more. Some private sector people will say maybe we ought to do it all or the labs would do it better than NIH or vice versa.

We really are delighted to hear all that. But our goal is to see if it is right to set a national goal to expedite and if it is, who ought to manage that, and if that is the case, what are the roles of the respective national institutions that are governmental, and then how should the private sector and university system fit into that.

Our attention here is on just this one piece of genome research, that is getting the mapping and sequencing done, not the research on using it. Clearly we understand that the knowledge obtained should be made broadly available because, it is a biomedical research tool once you have obtained the information.

Thank you very much, Mr. Chairman, for calling the hearing and for your genuine interest in this and in the other subjects that we have had hearings on. I would say, Mr. Chairman, we will hear again about technology transfer and I regret to have to burden you and the subcommittee with it all the time but Commerce is here and they are rather expert on analyzing the efficacy of the Department of Energy and other department's technology transfer programs. We may hear a little different version from Commerce than we heard from Dr. Decker last time about how they are going to expedite technology transfer with their new agreement and their new plan.

I hope Commerce is ready to give us their analysis of what it does and what it doesn't do. I think it would be rather revealing.

Thank you very much, Mr. Chairman.

[The prepared statement of Senator Domenici follows:]

OPENING STATEMENT OF
SENATOR PETE V. DOMENICI
COMMITTEE ON ENERGY AND NATURAL RESOURCES
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
HEARING TO CONSIDER THE HUMAN GENOME INITIATIVE TITLE OF S.1480, "THE DEPARTMENT OF ENERGY NATIONAL LABORATORY COOPERATIVE RESEARCH INITIATIVE ACT"

SEPTEMBER 17, 1987

MR. CHAIRMAN, THE WORLD IS ON THE VERGE OF MAKING MAJOR SCIENTIFIC BREAKTHROUGHS THAT COULD GREATLY IMPROVE THE QUALITY OF LIFE FOR ALL MANKIND. HUMAN GENETIC RESEARCH CURRENTLY BEING CONDUCTED BY SEVERAL FEDERAL AGENCIES, AND BY A NUMBER OF UNIVERSITIES AND PRIVATE BUSINESSES COULD GREATLY ENHANCE OUR UNDERSTANDING OF, AND ABILITY TO FIGHT, THOUSANDS OF HUMAN DISEASES - INCLUDING SUCH KILLERS AS CANCER, HEART DISEASE AND AIDS.

A POTENTIALLY ENORMOUS ARRAY OF DIAGNOSTIC, PREVENTIVE, AND TREATMENT SECRETS ARE CONTAINED IN THE HUMAN GENETIC CODE - OTHERWISE KNOWN AS THE "HUMAN GENOME."

DEVELOPMENT OF A THOROUGH UNDERSTANDING OF THE STRUCTURE AND FUNCTION OF OUR GENETIC CODE COULD REVOLUTIONIZE BIOLOGICAL SCIENCE BY VASTLY IMPROVING OUR UNDERSTANDING OF THE HUMAN BODY AND THE DISEASES THAT PLAGUE IT.

OVER THE PAST FEW YEARS SCIENTISTS HAVE BEGUN THE ENORMOUS TASK OF MAPPING AND SEQUENCING THE HUMAN GENOME - IDENTIFYING AND

LOCATING ALL THE GENETIC INFORMATION THAT GUIDES THE DEVELOPMENT AND FUNCTION OF THE HUMAN BODY.

ONCE THIS FRONTIER IS CROSSED, AND THE KNOWLEDGE IS APPLIED, WE MAY BE ABLE TO MAKE MAKE GREAT STRIDES TOWARD DISEASE CONTROL AND PREVENTION.

ALREADY, GENETIC MAPPING ADVANCES HAVE HAD A POWERFUL IMPACT ON THE DIAGNOSIS OF GENETICALLY-LINKED DISEASES, OF WHICH THERE ARE OVER 3,000 KINDS CURRENTLY KNOWN.

MANY OF THESE DISEASES ARE CAUSED BY AN ABNORMALITY IN A SINGLE GENE. IDENTIFICATION OF SOME OF THESE GENES HAS GREATLY HELPED IN THE FIGHT AGAINST DISEASES SUCH AS CYSTIC FIBROSIS, MUSCULAR DYSTROPHY, AND HUNTINGTON'S DISEASE BY IMPROVING EARLY DIAGNOSTIC CAPABILITIES.

IN ADDITION TO THE MANY DISEASES CURRENTLY KNOWN TO BE LINKED TO A GENETIC ABNORMALITY, ALMOST EVERYDAY SCIENTISTS SEEM TO FIND A GENETIC LINK TO ANOTHER AILMENT. RECENTLY, MANIC DEPRESSIVE ILLNESS WAS FOUND TO HAVE A GENETIC BASIS.

SCIENTISTS ARE ALSO DISCOVERING HOW GENETIC RESEARCH IS AIDING IN THE FIGHT AGAINST CANCER AND AIDS. A GENETIC BASIS WAS RECENTLY ESTABLISHED WITH COLON CANCER, AND JUST THE OTHER DAY GENETIC RESEARCH BEING CONDUCTED AT LOS ALAMOS NATIONAL LABORATORY IN MY STATE OF NEW MEXICO YIELDED AN IMPROVED UNDERSTANDING OF THE AIDS VIRUS' COMPLEX NATURE.

EVEN TECHNIQUES DEVELOPED BY GENETIC RESEARCH ARE BEING USED TO FIGHT DISEASES. SCIENTISTS ARE NOW ABLE TO CREATE HUMAN INSULIN ARTIFICIALLY, NO LONGER IS BOVINE INSULIN NEEDED OR USED IN HUMANS. RECENTLY IT WAS REPORTED THAT A GENETICALLY ENGINEERED DRUG HAS BEEN CREATED THAT CAN BOOST THE HUMAN IMMUNE SYSTEM IN AIDS PATIENTS.

WHILE IT IS NOT CLEAR TO WHAT EXTENT THIS RESEARCH WILL BENEFIT US, IT IS BECMMING INCREASINGLY CLEAR THAT BY MAPPING, AND EVENTUALLY SEQUENCING THE HUMAN GENOME, AN ENORMOUSLY USEFUL TOOL WILL HAVE BEEN CREATED THAT WILL LAUNCH US INTO A NEW ERA OF BIOLOGICAL AND MEDICAL SCIENCE.

THE KNOWLEDGE GAINED, AND THE COUNTLESS COMMERCIAL APPLICATIONS GENERATED BY THIS RESEARCH PROJECT WILL NOT ONLY SIGNIFICANTLY IMPROVE QUALITY OF LIFE IN THIS COUNTRY, BUT ALSO BRING GREAT ECONOMIC STRENGTH TO THE NATION THAT COMPLETES THE PROJECT.

HOWEVER, THE TASK OF MAPPING AND SEQUENCING THE HUMAN GENOME, IS A VERY LARGE ONE AND WILL REQUIRE COORDINATION BETWEEN MANY SCIENTIFIC DISCIPLINES AND THE MANY SCIENTIFIC RESOURCES OUR NATION POSSESSES.

COMPLETING THE MAP AND EVENTUALLY DETERMINING THE SEQUENCES OF THE HUMAN GENOME WILL REQUIRE CREATING AND APPLYING NEW TECHNOLOGIES THAT WILL SPEED THE PACE OF THE PROJECT.

WE IN THE UNITED STATES ARE FORTUNATE TO HAVE MANY CAPABLE AND DIVERSE INSTITUTIONS ALREADY WORKING ON MAPS AND SEQUENCES, AS WELL AS ON THE TECHNOLOGIES NEEDED TO FURTHER THIS WORK.

THE NATIONAL LABORATORIES, THE NATIONAL INSTITUTES OF HEALTH, THE NATIONAL SCIENCE FOUNDATION, OTHER AGENCIES, UNIVERSITIES AND COMMERCIAL FIRMS ALL HAVE BEEN CONDUCTING VALUABLE RESEARCH. YET, WE ARE NOT TAKING FULL ADVANTAGE OF ALL THESE GREAT SCIENTIFIC RESOURCES, NOR ARE WE MAKING SURE THAT THE FRUITS OF THIS WORK WILL QUICKLY FLOW TO AMERICAN INDUSTRY.

WHILE THESE INSTITUTIONS ARE ALL CONDUCTING THEIR OWN RESEARCH EFFORTS ON THE GENOME, OUR NATIONAL EFFORT AS A WHOLE IS NOT WELL COORDINATED OR FOCUSED. NOR DO THE VARIOUS INSTITUTIONS WORKING ON THIS PROJECT TAKE FULL ADVANTAGE OF THE EXPERTISE AND CAPABILITIES THAT EACH OTHER POSSES SUCH THAT THE PROJECT WILL PROCEED AS QUICKLY AS POSSIBLE AND THAT THE KNOWLEDGE GAINED IS QUICKLY CONVERTED INTO USEFUL COMMERCIAL APPLICATIONS.

TO HELP FOCUS AND COORDINATE WHAT NEEDS TO BE A NATIONAL EFFORT IN SEVERAL SCIENTIFIC AREAS, I INTRODUCED S.1480, THE "DEPARTMENT OF ENERGY NATIONAL LABORATORY COOPERATIVE RESEARCH INITIATIVE ACT." WE ARE MEETING HERE TODAY TO CONSIDER TITLE 2 OF THAT BILL, THE GENOME MAPPING INITIATIVE.

S.1480 RECOGNIZES THE EXTENSIVE RESEARCH ACCOMPLISHMENTS AND CAPABILITIES OF THE DEPARTMENT OF ENERGY'S NATIONAL LABORATORIES AND CITES THE GREAT POTENTIAL THE LABORATORIES HAVE TO ADVANCE THE GENOME PROJECT. MY BILL WOULD PROVED FOR IMPROVED COORDINATION AND DIRECTION OF HUMAN GENOME RESEARCH ACTIVITIES BEING CONDUCTED BY THE NATIONAL LABORATORIES, AND OTHER GOVERNMENT, UNIVERSITY AND COMMERCIAL INSTITUTIONS.

THE BILL ESTABLISHES A "NATIONAL POLICY BOARD" TO COORDINATE ACTIVITIES AND POLICIES OF THE VARIOUS GOVERNMENT AGENCIES INVOLVED IN GENETIC RESEARCH. RELEVANT NON-GOVERNMENTAL INSTITUTIONS WOULD BE REPRESENTED ON THE BOARD AS WELL.

THE BILL WOULD ALSO ESTABLISH A "CONSORTIUM" OF U.S. INDUSTRY, UNIVERSITY, AND OTHER GOVERNMENT AGENCIES TO DIRECT THE DAY-TO-DAY WORK. THIS CONSORTIUM WOULD HELP ASSURE THAT THE PRODUCTS OF RESEARCH ARE WIDELY DISSEMINATED AMONG U.S. COMPANIES.

THE DEPARTMENT OF ENERGY RESEARCH PROGRAM WOULD FOCUS UPON NEW TECHNOLOGIES AND METHODS FOR ADVANCING HUMAN GENOME RESEARCH, INCLUDING DATA STORAGE AND DISSEMINATION EQUIPMENT.

INTELLECTUAL PROPERTY RIGHTS WOULD BE CONTROLLED UNDER THIS BILL SUCH THAT U.S. COMPANIES WOULD BE ABLE TO QUICKLY UTILIZE THE KNOWLEDGE AND DEVICES DEVELOPED BY THE CONSORTIUM.

SINCE S. 1480'S INTRODUCTION MANY AGENCIES AND GROUPS HAVE COMMENTED ON THE BILL AND MADE VERY HELPFUL SUGGESTIONS ABOUT CHANGES. I VERY MUCH WELCOME AND APPRECIATE THE COMMENTS I AND MY STAFF HAVE RECEIVED AND LOOK FORWARD TO THE COMMENTS AND SUGGESTIONS TO BE MADE TODAY.

DURING EARLIER DISCUSSIONS IT WAS SUGGESTED, FOR INSTANCE, THAT WE CLARIFY IN THE BILL THAT ALL CONTRACTS ENTERED INTO BY THE LABORATORIES BE SUBJECT TO DEPARTMENT OF ENERGY APPROVAL, AND THAT A NATIONAL SECURITY EXEMPTION BE MADE. I SUPPORT MAKING THESE CHANGES.

OTHERS HAVE SUGGESTED THAT VARIOUS ASPECTS OF THE POLICY BOARD AND CONSORTIUM BE CHANGED TO IMPROVE REPRESENTATION AND THE ABILITY OF THE TWO ENTITIES TO CARRY OUT THEIR MISSIONS. QUESTIONS ALSO HAVE BEEN RAISED ABOUT THE BEST WAY TO HANDLE THE TRANSFER OF TECHNOLOGY AND KNOWLEDGE TO COMMERCIAL USE.

WE WILL, OF COURSE, CONTINUE DISCUSSING THESE ISSUES TODAY, HOWEVER, THERE MAY NOT BE ENOUGH TIME TO COMPLETE DISCUSSION ON THE TECHNOLOGY TRANSFER ISSUES. IT MAY BE DESIRABLE TO HOLD ANOTHER HEARING SOMETIME SOON TO COMPETE OUR DISCUSSION.

MR. CHAIRMAN, I THANK YOU FOR HAVING THIS HEARING TODAY AND I THANK ALL WHO HAVE COME TO TESTIFY FOR PROVIDING YOUR VALUABLE INPUT INTO MAKING THIS LEGISLATION AND THIS CRITICAL NATIONAL ENDEAVOR A SUCCESS. I LOOK FORWARD TO TODAY'S TESTIMONY.

STATEMENT OF HON. WENDELL H. FORD, A U.S. SENATOR FROM THE STATE OF KENTUCKY

Senator **Ford**. I ask that my statement be included in the record.

We all know that this is a complex field, but thanks to some foresighted Senators, i.e. Senator Domenici, S. 1480 has been introduced, that will make significant changes in the way that research and development is carried out in this complex and important field.

Many of us feel that an aggressive program to map the human genome will revolutionize biology and medicine. The bottom line, and my feeling about it, this could also provide powerful tools to diagnose and prevent disease. As I heard the professor say in school one time, you may not like me when I leave here, when you leave here, but there may be the answer to cancer in the minds of one of these students and I intend to find it if it's there.

Our intent here to to try to find it if it's there, and hopefully in the minds of those who are testifying and bringing this information to us, we can develop something that will encourage and make a better life.

I was struck by a statement the other day about how many people in this country are going to be 100 years old by the year 2000. I intend to be here to see if that is true, but I do not know whether it will be or not.

Any other Senator wish to have an opening statement; Senator Evans?

[The prepared statements of Senator Ford and Senator Johnston follow:]

STATEMENT OF SENATOR WENDELL FORD

CHAIRMAN, SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

HEARING ON S. 1480

"THE DEPARTMENT OF ENERGY NATIONAL LABORATORY
COOPERATIVE RESEARCH INITIATIVES ACT"

SEPTEMBER 17, 1987

I AM PLEASED TO BE HERE TODAY TO CONTINUE THE SUBCOMMITTEE'S HEARINGS ON SENATOR DOMENICI'S BILL, S. 1480, THE DEPARTMENT OF ENERGY NATIONAL LABORATORY COOPERATIVE RESEARCH INITIATIVES ACT.

S. 1480 WOULD ENHANCE THE ROLE OF THE DEPARTMENT'S NATIONAL LABORATORIES IN THREE SPECIFIC AREAS -- SUPERCONDUCTIVITY, SEMICONDUCTORS, AND MAPPING OF THE HUMAN GENOME. S. 1480 SEEKS TO TAP THE EXPERTISE OF THE NATIONAL LABORATORIES AND ESTABLISH A FRAMEWORK FOR COOPERATION BETWEEN FEDERAL AGENCIES, UNIVERSITIES, AND PRIVATE FIRMS TO HELP COMMERCIALIZE THIS TECHNOLOGY.

EARLIER THIS WEEK, WE HEARD FROM WITNESSES ON THE ISSUES OF SUPERCONDUCTIVITY AND SEMICONDUCTORS. TODAY'S HEARING WILL FOCUS ON THE THIRD MAJOR AREA: MAPPING THE HUMAN GENOME.

THE HUMAN GENOME IS THE SET OF GENETIC INSTRUCTIONS GUIDING THE DEVELOPMENT AND FUNCTIONING OF CELLS OF THE HUMAN BODY. THE GENOME DETERMINES WHICH CELLS FORM EACH ORGAN. THE GENOME OF AN INDIVIDUAL ALSO DETERMINES THE LIKELIHOOD OF DEVELOPING KNOWN GENETIC DISEASES AND THE LIKELIHOOD TO DEVELOP OTHER MORE COMMON DISEASES.

THUS, AN ABILITY TO READ THE INSTRUCTIONS ENCODED IN THE GENOME COULD HELP IDENTIFY INDIVIDUALS AT RISK IN A GIVEN ENVIRONMENT. IT COULD ALSO HELP DEVELOP NEW METHODS FOR TREATING DISEASE.

THIS IS A COMPLEX FIELD. RESEARCH IS UNDERWAY AT OUR NATIONAL LABORATORIES. THERE IS GREAT POTENTIAL FOR EXPANDING THE STATE OF KNOWLEDGE IN THIS FIELD.

PROPONENTS OF AN AGGRESSIVE PROGRAM TO MAP THE HUMAN GENOME BELIEVE THAT THIS WILL REVOLUTIONIZE BIOLOGY AND MEDICINE. THIS COULD ALSO PROVIDE POWERFUL TOOLS TO DIAGNOSE AND PREVENT DISEASE.

FEDERAL RESEARCH ON THE HUMAN GENOME IS NOW CONCENTRATED PRIMARILY IN TWO AGENCIES -- THE DEPARTMENT OF ENERGY AND THE NATIONAL INSTITUTES OF HEALTH. DOE'S RESEARCH IN THIS AREA IS COORDINATED BY ITS OFFICE OF HEALTH AND ENVIRONMENTAL RESEARCH. DOE-SUPPORTED WORK IS CARRIED OUT AT LAWRENCE LIVERMORE NATIONAL LABORATORY, LOS ALAMOS NATIONAL LABORATORY, AND COLUMBIA UNIVERSITY.

S. 1480 WOULD MAKE SIGNIFICANT CHANGES IN THE WAY THAT RESEARCH AND DEVELOPMENT IS CARRIED OUT IN THIS COMPLEX AND IMPORTANT FIELD. THESE CHANGES ARE INTENDED TO DRAW TOGETHER FEDERAL RESEARCH IN THIS AREA AND ESTABLISH A FRAMEWORK TO ALLOW COMMERCIALIZATION.

I AM ANXIOUS TO HEAR FROM OUR DISTINGUISHED WITNESSES ON THE STATE OF KNOWLEDGE ON THE HUMAN GENOME AND ON THE POTENTIAL FOR EXPANDING ON THAT KNOWLEDGE THROUGH ENHANCED RESEARCH. THESE ARE IMPORTANT ISSUES TO BE ADDRESSED.

OUR FIRST PANEL OF WITNESSES THIS AFTERNOON WILL PROVIDE TESTIMONY FROM THE FEDERAL AGENCIES INVOLVED IN RESEARCH IN THIS IMPORTANT AREA.

STATEMENT OF SENATOR J. BENNETT JOHNSTON

HEARING ON S. 1480

"THE DEPARTMENT OF ENERGY NATIONAL LABORATORY COOPERATIVE RESEARCH INITIATIVES ACT"

SEPTEMBER 17, 1987

I AM PLEASED THAT THE HEARINGS ARE CONTINUING TODAY ON SENATOR DOMENICI'S BILL, S. 1480, THE DEPARTMENT OF ENERGY NATIONAL LABORATORY COOPERATIVE RESEARCH INITIATIVES ACT. THIS BILL, TOGETHER WITH THE AMENDMENTS TO THE BILL THAT SENATOR DOMENICI HAS INTRODUCED, WOULD CHANGE THE RESEARCH ENVIRONMENT IN THE DOE NATIONAL LABORATORIES IN A WAY THAT WILL PROMOTE MUCH MORE INVOLVEMENT WITH UNIVERSITIES AND PRIVATE FIRMS. TODAY WE ARE GOING TO DISCUSS THE PORTION OF THE BILL THAT DEALS WITH RESEARCH ON THE MAPPING OF THE HUMAN GENOME.

AS I UNDERSTAND IT, THE HUMAN GENOME IS THE NAME GIVEN TO NATURE'S COMPUTER PROGRAM FOR A HUMAN BEING. BY STUDYING AND MAPPING THE HUMAN GENOME WE WILL BE LEARNING ABOUT THE INDIVIDUAL INSTRUCTIONS IN THE PROGRAM - THE PROGRAM STEPS - AND HOW THEY ARE ARRANGED TO RESULT IN A FUNCTIONING HUMAN BEING. IF WE UNDERSTOOD THIS PROGRAM, WE WOULD UNDERSTAND HOW EVERYTHING HAPPENS IN A HUMAN BODY. THE DOE INTEREST IN THIS RESEARCH COMES FROM THE DEPARTMENT'S INTEREST IN HEALTH EFFECTS OF RADIATION AND OTHER BY-PRODUCTS OF ENERGY DEVELOPMENT. THE WAY IN WHICH THESE

AGENTS AFFECT A HUMAN BODY CAN BE CLARIFIED BY STUDYING THE GENOME. IN FACT, THE WAY ANY DISEASE ATTACKS THE HUMAN BODY OUGHT TO BE UNDERSTANDABLE THROUGH THIS RESEARCH.

BECAUSE OF THIS, OTHER FEDERAL AGENCIES, IN PARTICULAR, THE NATIONAL INSTITUTES OF HEALTH, ARE INVOLVED IN GENOME RESEARCH. THE DOMENICI BILL IS ATTEMPTING TO ENLIST THE DOE NATIONAL LABORATORIES IN AN EFFORT TO COORDINATE THIS RESEARCH SO THAT WE HAVE AS LITTLE WASTE AS POSSIBLE IN AN EFFORT THAT, IF FULLY IMPLEMENTED, WILL COST BILLIONS OF DOLLARS. ANY SUCH ATTEMPT AT COORDINATION IS BOUND TO BE CONTROVERSIAL, JUST BECAUSE THIS MUCH MONEY INVITES BATTLES OVER TURF.

SO, IN ADDITION TO SOME FASCINATING BIOLOGICAL SCIENCE, THERE IS SOME INTERESTING POLITICAL SCIENCE INVOLVED IN THIS ISSUE.

STATEMENT OF HON. DANIEL J. EVANS, A U.S. SENATOR FROM THE STATE OF WASHINGTON

Senator **Evans**. Mr. Chairman, I don't have a full opening statement, but I am delighted to be here as an engineer who is rapidly finding that engineering today has proceeded far beyond anything I ever studied, and almost beyond comprehension.

I think it is terribly important for us to get as much information as we can, to try to determine how best to proceed. I have not made up my mind at all as to whether changes are necessary and, if so, what changes would be beneficial in allowing us to continue the research which is so critical, and how to conduct it in the best and most efficient manner possible.

I think, Mr. Chairman, the terms efficiency and research are sometimes counteractive. You cannot always be totally efficient when you are especially engaged in basic research which just does not simply and easily fall into a step-by-step proposition. We are dealing in this hearing with several of the most important issues that have come up scientifically in many, many years. I think the real question is whether we have to make some choices, at least insofar as federal investment is concerned when there are so many areas of such great importance which deserve additional research and attention.

I hope we can find as many of them as possible, but in order to do that, we will have to be as clever as possible in how we use additional funds.

Senator **Ford**. Senator Hecht?

Senator **Hecht**. No.

Senator **Ford**. Thank you very much. Dr. Decker, we will start with you and work across the table. And your statements will be included in the record in full. If you would like to highlight it that would be perfectly all right with the Chairman.

STATEMENT OF DR. JAMES F. DECKER, ACTING DIRECTOR, OFFICE OF ENERGY RESEARCH, DEPARTMENT OF ENERGY

Dr. **Decker**. Thank you very much, Mr. Chairman.

I am pleased to be here with you again today to discuss another area of the Department of Energy's research related to S. 1480.

On Tuesday, I described the Department's research programs and technology transfer activities related to superconductivity. Today, I will discuss the Department's efforts aimed at developing the technologies and resources necessary to characterize the molecular nature of the human genome. Let me reiterate what I said on Tuesday, that the Department fully supports the goal of S. 1480, which is to improve the cooperation among universities, industry and the national laboratory system of the Department in several specific areas of technology.

First I will comment on the Department's interest in the human genome initiative; second, on our ongoing and proposed activities related to the human genome and third; on how our activities are being coordinated with those of other involved organizations.

The human genome is a complete set of genes or genetic instructions guiding the development and functioning of human beings. An individual's genome or set of genes specifies that person's unique genetic inheritance. A person's genome also determines whether one will develop one or more of the 3,000 known genetic diseases. It also influences the chances of developing other diseases with more complex causes, such as heart disease and cancer.

We believe that the Department's efforts, aimed at creating new technologies and resources for broad application in biology, offer significant opportunities for joint efforts with industry and universities, to accelerate the development of the nation's biotechnology industry. Technology development is the key to success in the human genome project, and we intend to work closely with industry in this endeavor. It is the goal of the Department's human genome initiative to create the tools, technologies and resources which will allow efficient decoding of the molecular structure on a human genome.

The research proposed by the Department is a logical outgrowth of ongoing DOE research and builds on capabilities and strengths of the Department and its national laboratory system. The proposal represents a new approach to a traditional DOE mission, namely to understand the long-term implications of energy technologies. Health and environmental concerns are at the core of major energy policy questions that confront the Department and the nation. Such concerns will have a major, perhaps deciding influence on the mix of energy technologies with which we move forward into the future. The primary health-related question faced by the Department centers on the long term, such as the impact of low levels of radiation and energy related chemicals.

The ability to characterize an individual's genetic makeup will vastly increase our ability to identify individuals who might be particularly susceptible to low levels of toxic agents and to identify cellular agents years before symptoms appear.

This capability therefore will have a substantial impact on disease prevention and treatment. It is worth noting that technologies developed during the genome initiative are likely to have significant application in the private sector, as did the results of DOE funded research in nuclear medicine. An estimated 80 million to 100 million nuclear medicine procedures are performed annually in the U.S. Nuclear medicine has spawned industries valued at hundreds of millions of dollars a year. The technologies developed during the genome initiative are likely to produce even more impressive results in the private sector.

Research relating to the genome initiative has been underway at the Department since 1983 when the Department initiated a project called the National Laboratory Gene Library Project. The purpose of this ongoing project is to separate human chromosomes and prepare cloned DNA fragments from each type of chromosome. The project uses the unique strengths of Los Alamos and Lawrence Livermore National Laboratories in the area of chromosome separation using flow cytometry, a Los Alamos invention.

The libraries of cloned DNA fragments from each chromosome are a valuable research resource for the medical genetics community. This has been a cooperative project with the National Institutes of Health. The libraries are made available to the world scientific community as a repository funded by the National Institutes of Health.

The Department's fiscal 1988 request in the President's budget submission to Congress for the human genome initiative is $12 million. The program is envisioned as a coordinated, multidisciplinary effort to create the technologies and resources which would allow physical mapping and sequencing of the human genome, perhaps by the end of the century.

The first phase would be completed in five or six years and has three major goals; first, the development of innovative, high speed, fully automated technologies necessary for large scale mapping and sequencing of DNA; second, to develop a computerized data base and analytical tool to make available, manage and understand the vast amounts of data to be generated; and third, production of an ordered set of DNA fragments of the human genome, which is a logical outgrowth of the Gene Library Project.

The second phase of a human genome program, would concentrate on the actual sequencing of the human genome, and would be heavily dependant on the results of the first phase.

While our first phase effort is modest in size, it is essential, in my view, for the ultimate prospect of sequencing some 3 billion nucleotides at a present cost of around a dollar apiece, that new techniques and approaches be found to greatly lower these costs and increase the speed of the process. The development of those new technologies will require a multidisciplinary approach involving scientists and engineers from a variety of fields. And this is a particular strength of the DOE laboratories.

Senator **Domenici**. Might I clarify, so you will not be worried, all these Senator's did not leave because of your testimony. We have not said anything that shocking yet. The first buzzer means a vote is on, and so we are trying to rotate. They will get down there and vote so we do not have to stop. I figured you would be to the bad part of your testimony and they would not be back yet. I was rather hopeful that you would get through it and they would never hear it, but go ahead.

Dr. **Decker**. I do not really think there is a bad part of my testimony.

The Secretary of Energy has announced centers at the Los Alamos National Laboratory and the Lawrence Berkeley National Laboratory to study the human genome. These centers will develop new technolgy required for the project and carry out research on physical mapping, cloning and eventual sequencing of the human genome. Work at these centers will be done in cooperation with efforts at universities, the private sector, Lawrence Livermore National Laboratory, Pacific Northwest National Laboratory, and other DOE laboratories.

Los Alamos has been asked to explore the possibilities for cooperative research programs with the private sector to develop commercial applications of human genome research. As I mentioned on Tuesday, Los Alamos has been given a similar assignment in the superconductivity area.

Let me turn to coordination among the various federal agencies involved. Currently, interagency coordination in this area is carried out through the Domestic Policy Council's Working Group on Biotechnology. That working group has set up a subcommittee on the human genome. It has representatives from the National Institutes of Health, National Science Foundation, Food and Drug Administration, the Department of Agriculture, Environmental Protection Agency, and the Office of Science and Technology Policy, as well as DOE. The subcommittee helps to ensure that the research programs of each agency complement each other.

We believe that this mechanism is operating well and we are committed to its effective use. Further evidence of our cooperation with the National Institutes of Health is that, through the kindness of Dr. Wyngaarden, NIH has detailed a scientist to work with our office of Health and Environmental Research and I am sure that that will help to coordinate our two activities even more.

As I noted earlier, the Department fully supports the goal of this bill. As you know, I expressed some concerns of the Department during my appearance here on Tuesday. I will not repeat those concerns. I understand that the bill is undergoing some revisions that will affect some of our areas of concern.

Thank you, I will be glad to answer any questions.

[The prepared statement of Dr. Decker follows:]

Statement of James F. Decker

Acting Director of the Office of Energy Research

U.S. Department of Energy

before the

Subcommittee on Energy Research and Development

of the

Senate Energy and Natural Resources Committee

September 17, 1987

Mr. Chairman and Members of the Subcommittee:

I am pleased to be here with you again today to discuss another area of the Department of Energy's (DOE) research. On Tuesday, I described the Department's research programs and technology transfer activities in superconductivity and semiconductors. Today I will discuss DOE's efforts aimed at developing the technologies and resources necessary to characterize the molecular nature of the human genome, the complete set of genes that make-up a human being. I would like to begin by providing a few words of background on the subject of our discussion--the human genome--and then I will discuss the Department's historic involvement in genetic research, as well as our ongoing and proposed activities related to the human genome and how they are being coordinated with other involved organizations. I will also make some comments on selected aspects of S. 1480. As I noted in my earlier testimony, one of our major concerns is that the authority that the bill provides to DOE's laboratory contractors to make unilateral funding decisions would have a negative impact on the Department's ability to manage its programs effectively. I will discuss this and other aspects of S. 1480 later in my statement. We have a number of other real concerns which we currently are discussing with Subcommittee staff.

First, let me reiterate that the Department fully supports the goal of S. 1480, which is to improve the cooperation among universities, industry and the national laboratory system of the Department. We believe that DOE's efforts aimed at creating new technologies and resources for broad application in biology offer significant opportunities for joint efforts with industry and universities to accelerate the development of the nation's biotechnology industry. Technology development is the key to success in the human genome project; and we intend to work closely with industry in this endeavor.

THE HUMAN GENOME

The human genome is the complete set of genes, or genetic instructions, guiding the development and functioning of a human being. An individual's genome, or set of genes, specifies that person's unique genetic inheritance. A person's genome also determines whether one will develop one of the more than 3000 known genetic diseases and it influences the chances of developing other diseases with more complex causes such as heart disease and cancer.

There are an estimated 100,000 human genes that are encoded in DNA, deoxyribonucleic acid. DNA is constructed of long chains of molecular building blocks called nucleotides. Information in DNA is encoded by the ordering of its nucleotides. There are approximately 3 billion nucleotides comprising the human genome. These three billion nucleotides are packaged into 23 pairs of chromosomes. The connection between the structure of DNA and the inheritance of characteristics is the fundamental concept in modern molecular biology. It is the goal of the Department's human genome initiative to create the tools, technologies and resources which would allow the efficient decoding (i.e., physical mapping and sequencing) of the molecular structure of the human genome.

Two different but related tasks are involved in understanding the human genome. The first, physical mapping of the human genome, entails fragmenting the genome into smaller pieces or clones, and then determining the order of these clones in the genome structure. This ordered set is then permanently available as a source of cloned DNA for investigators working on particular genes. It also serves as a general road map to guide genetic mapping and DNA sequencing projects. The second task is to determine the DNA sequence of each clone, leading in an ordered manner to the eventual sequence determination of the entire three billion nucleotides of the human genome. The larger task of human genetics is to use this information to better understand the development of the human organism, to understand diseases, to explain physiological functions and to understand the basis for individual genetic differences.

DOE HUMAN GENOME INITIATIVE

The research proposed by the Department is a logical outgrowth of ongoing DOE research and builds on the capabilities and strengths of the Department and its national laboratory system. The proposal represents a new approach to a traditional DOE mission, namely, to understand the long-term health implications of energy technologies. Health and environmental concerns must be understood before major energy policy questions that confront the Department and the Nation can be resolved. Such concerns will have a major, perhaps deciding, influence on the mix of energy technologies with which we move into the future. The primary health-related question faced by the Department centers on the long-term impacts of low levels of radiation and energy-related chemicals. The major concerns are possible cancers in today's generation, as well as the legacy that is left to future generations in the form of heritable mutations.

Over the years, a variety of approaches have been used to evaluate the effects of low levels of radiation and energy-related chemicals. Each of these approaches has its limitations. At high levels of exposure, virtually everyone is affected; but at levels typically encountered in our daily lives only a few suffer health impacts. A major explanation for this individual variation in susceptibility or resistance lies in differences in genetic characteristics. The ability to characterize an individual's genetic makeup will vastly increase our ability to identify individuals who might be particularly susceptible to low levels of toxic agents and to identify cellular changes years before symptoms appear. This capability, therefore, will have a substantial impact on disease prevention and treatment.

It is worth noting that the technologies that will develop in carrying out the genome initiative are highly likely to have significant application in the private sector, as did the results of DOE-funded research in nuclear medicine. An estimated 80 to 100 million nuclear medicine procedures are performed annually in the U.S.; and nuclear medicine has spawned industries valued at hundreds of millions of dollars a year. From what we know today, we believe that the technologies developed during the genome initiative will probably produce even more impressive results in the private sector.

Research leading to the genome initiative has been underway at DOE since 1983 when the Department initiated a project called the National Laboratory Gene Library Project. The purpose of this ongoing project is to separate human chromosomes and prepare cloned DNA fragments from each type of chromosome. The Project uses the unique strengths of Los Alamos and Lawrence Livermore National Laboratories in the area of chromosome separation using flow cytometry, a Los Alamos invention. The library of cloned DNA fragments from each chromosome is a valuable research resource for the medical genetics community. The libraries are made available to the world scientific community through a repository funded by the National Institutes of Health. The Department's FY 1988 request in the President's budget submission to Congress to carry out our human genome initiative is $12 million. The program is envisioned as a focused, coordinated, multidisciplinary effort to create the technologies and resources which would allow physical mapping and sequencing of the human genome, perhaps by the end of the Century. This coordinated focus on technology development is distinct from the current national effort in human genetic research. The first phase, to be completed in five or six years, has three goals: 1) development of innovative, high-speed, fully automated technologies necessary for large-scale mapping and sequencing of DNA; 2) development of the computerized database and analytical tools to make available, manage and understand the vast amount of data to be generated as a by-product and in conjunction with results from other federally funded research; and 3) production of a complete physical map of the human genome, which is a logical outgrowth of the Gene Library Project. The second phase of the program would concentrate on the actual sequencing of the human genome and would be heavily dependent on the results of the first phase. We expect that this research will continue to be carried out by the entire biomedical research community with the tools we develop.

In FY 1987 approximately $5 million was spent on the human genome activity relevant to the FY 1988 initiative. This includes funds supplied by DOE to support the ongoing National Laboratory Gene Library Project I mentioned earlier. It also includes mapping efforts at Columbia University, and the Lawrence Livermore and Los Alamos National Laboratories, as well as technology development efforts at Harvard and three of DOE's national laboratories. FY 1987 funding also included the Department's support of GenBank, the national databank of nucleic acid sequences (co-funded by DOE, NSF and NIH), and the development of new analytical tools for data analysis. In FY 1988, we anticipate expanded efforts aimed at all of the goals of phase one. The exact distribution of funds will depend on the quality and quantity of proposals as evaluated by peer review panels, but there is likely to be considerable focus on the development of innovative sequencing and mapping technologies. Support of physical mapping and computer database and computational aspects will also increase.

In addition, the Secretary of Energy has directed Los Alamos National Laboratory and Lawrence Berkeley National Laboratory to establish centers to study the human genome. These centers will develop new technology required for the project and carry out research on physical mapping, cloning and, eventually, sequencing the human genome. The Los Alamos and Berkeley centers will have a major responsibility to coordinate efforts to transfer to the private sector the human genome research results developed at all of DOE's national laboratories. Los Alamos has been asked to explore the possibilities for cooperative research programs with the private sector to develop commercial applications of human genome research. These explorations could lead to a pilot program which could be a model for other DOE laboratories. Work at these centers will be established in cooperation with efforts at universities, the private sector, Lawrence Livermore National Laboratory, Pacific Northwest Laboratory and other DOE laboratories.

COORDINATION

The Department's major role in this multiagency effort reflects the necessary combination of intellectual and physical resources that exist within the Department and its laboratories. It also reflects the Department's experience and infrastructure for handling high technology, interdisciplinary projects involving national laboratories, universities and industry. But it is also clear that a focused, coordinated multidisciplinary effort involving industry, universities and national laboratories, and several modes of funding, from individual investigators to multidisciplinary centers will be necessary to obtain the most efficient progress.

Interagency coordination in this area up to the present time has been carried out through the Domestic Policy Council's Working Group on Biotechnology. The Working Group has a Subcommittee on the Human Genome with representatives from NIH, DOE, NSF and the Food and Drug Administration. This Subcommittee gathers information on the relevant activities of each agency, thus helping to ensure that the research programs of each agency complement each other. We believe that this mechanism is operating well and are committed to its effective use.

Since the focus of the DOE initiative is on development of new technologies and resources, it is most appropriate that the private sector be intimately involved in the project. It is our intent to seek private sector participation, including cost-sharing where appropriate. A number of cooperative interactions with various companies has already begun. We will encourage each laboratory to seek such industrial participation in its part of the project. In addition, we will set up a central administrative office whose responsibilities will include taking the lead in exploring general possibilities for cooperative research programs with the private sector and for facilitating efficient transfer of all newly developed technology.

S. 1480

The Department believes that existing coordination mechanisms are working effectively to achieve our goals in the genome initiative and are meeting the objectives of the bill. With regard to the proposed Policy Board, we believe that there are existing mechanisms in place which will ensure interagency coordination and effective policy guidance.

As I noted earlier, the Department fully supports the goal of the bill. However, it is very important that the Department retain its ability to carry out its oversight role on content and progress in the research program. It is equally important for the Department to have an effective program management role in the operation and review of its laboratories. Let me reiterate the concerns I expressed during my appearance here on September 15, 1987.

Laboratory contractors should not have the discretion to commit public funds unilaterally without DOE's knowledge and approval. Such a situation would cause many problems. For example, funds for research to be carried out in any given year are proposed, approved and are made available as a part of the annual budget process. This process cannot anticipate unilateral commitments made by laboratory contractors. The discretion assigned to laboratory contractors could also have the effect of abrogating the Federal Government's responsibility to manage its programs.

The Department strongly believes that DOE should review cost-sharing agreements that could result in future year mortgages for the Department. In addition, a number of provisions in the proposed bill require additional study. For example, the Office of Management and Budget's Office of Federal Procurement Policy, in accordance with Executive Order No. 12591, is developing a government-wide policy regarding ownership of technical data produced under federal contracts. Legislation which provides no standards and applies to a single initiative of a single agency would, under these circumstances, be premature.

In conclusion, let me say again that the Department agrees completely with the goal of S. 1480, but believes that it already has the necessary legislative authority to carry out its mission in the areas identified in the bill.

This concludes my prepared statement. I will be happy to answer questions.

Senator **Domenici**. I greatly appreciate, not only your testimony, this has been a busy week for you, and we have imposed upon your time twice, the day before yesterday and today in these areas, and we greatly appreciate the preparation that obviously went into it and the time that you have taken to study the proposal and be here with us.

Might I say, before the next witness and before the remaining witnesses testify, that with reference to the genome part of the bill, obviously a lot of negotiating went on from the time it was introduced until now. One of the reasons being is that much rhetoric about the trade bill being the vehicle to enhance America's competitiveness occurred here in the United States Senate, and a number of initiatives regarding applied science or the application of new technology was part of that bill.

We were hopeful that we could get something like this bill in that trade bill. That became impossible because of committee jurisdiction questions and the inability to get everybody together. In the meantime you should know that as sponsor, and of course it is up to the committee, we have already expressed a willingness to change some significant aspects.

The national policy board would have some changes, that is where it would be placed. DOE, NIH, OSTP, or somewhere else, who should Chair, Secretary of Energy, Director of NIH, head of OSTP or rotating chairs, could the board be better balanced to allow for more university and private sector representation, is a change needed there. None of these issues have been settled, though everyone should know that we are considering changes in those areas as we proceed and I as sponsor certainly am.

You may want to ask questions with reference to that even of me, and I would be delighted to respond as you give your testimony. Let me say now to the Director of NIH, I would very much like you to know that we have no pride of authorship with reference to this bill. We have no vested interest in titles, subtitles, or even the caption of the bill.

We wanted, because we thought the Department of Energy was involved, to try to proceed with some overall program. If it is helpful to you over the long haul that the title on genome mapping even be released from the generic title of this bill with reference to the Department of Energy National Laboratory Cooperative Research Initiative Act, and if you want to call it the National Institutes of Health Research Initiatives Cooperation Act, if that will help your temperament in any way we will do that, I assure you.

Having said that, I also want you to know that this Senator thinks you already are a premier institution, probably the best in the world, and I don't want you to think that because we are trying to create a policy board to direct and expedite human genome mapping that that is a reflection upon your National Institutes of Health work at all. It is not. We are just concerned that the United States ought to move rapidly and that ought to be coordinated, and no one has convinced me yet that we shouldn't move rapidly. Essentially that is how we got into this, having talked to some scientists about how to do it.

We also know that perhaps the national laboratories more than the NIH, although I am not expert enough to say it for certain, need to make the national laboratories more "user friendly," and we might even have to change, have a cultural type of change out there in the marketplace where they are more integrated for some of their work with universities and private sector institutions, and that may be tough to do. But I now have at least settled on that phrase, "user friendly," it sounds right to me.

A cultural change may be required, that sounds good to me and means it might be tough to do. But some of our goals here are aimed at both of those and I think you can see them as you understand the bill.

Please proceed, Doctor.

STATEMENT OF DR. JAMES B. WYNGAARDEN, DIRECTOR, NATIONAL INSTITUTES OF HEALTH, PUBLIC HEALTH SERVICE, DEPARTMENT OF HEALTH AND HUMAN SERVICES, ACCOMPANIED BY DR. RUTH KIRSTEEN

Dr. WYNGAARDEN. Thank you, Senator Domenici.

Let me also mention that I am accompanied by Dr. Ruth Kirsteen, who is the Director of the National Institute of General Medical Sciences and which institute the bulk of our work in genetics and fundamental sciences, and also by Dr. Donald Lindberg, Director of the National Library of Medicine which has a great interest in the information handling in the biotechnology field. They are available for responses later if you wish.

I would also like to comment briefly on your opening remarks and most recent remarks to commend you for the statement you have made, the deep understanding that you clearly have of this very important problem and the initiative that you have shown in addressing a very vital issue and for your flexibility in considering some modifications of the initial proposal.

I think that spirit of cooperation and collegiality is exactly right for this field and already exists, and we want to enhance it further.

I am pleased to have this opportunity to describe the activities of the NIH in mapping the human genome. As you know, Mr. Chairman, we are currently in the midst of an explosion in biological knowledge. This greatly accelerated pace of discovery really started when the genetic material DNA was found in 1953 to have a very precise structure arranged in a double helix.

Inherent in this structure was the basis for passage of genetic information from one generation to the next, and for this discovery, Dr. James Watson, an American, and his British colleague, Dr. Francis Crick, were awarded the Nobel Prize.

Since then, discovery after discovery in the area of genetics has come so rapidly that the term "biological revolution" is often used. A great majority of these findings have come from American scientists supported by NIH. Six additional Nobel Prizes have been awarded to scientists who work on DNA structure, all of whom received substantial support from NIH. The Congress of the United States has consistently supported the NIH budget for this work.

Another major discovery is a technique known as recombinant DNA technology, which permits the snipping of a small piece of DNA from one side of the gene and its insertion into another, even into the DNA of a different organism if that is desired. Again, this discovery was made by NIH supported scientists who also won the Nobel Prize.

The use of this technology has not only spawned a new biotechnology industry able to produce chemicals and drugs, but it has also made it possible to map and eventually to sequence the entire human genome, the complete genetic material of man. This latter project is actually feasible now, and with further methodological advances will be easier and cheaper in the future.

In Fiscal Year 1986, NIH provided over $300 million of its funds to about 3,000 research projects related to the elucidation of the complete genomes, of which about $100 million was related to the mapping and sequencing of the human genome.

Scientists supported by NIH are now engaged in a concerted effort to pay or pinpoint the specific location of genes on chromosomes, especially those genes responsible for inherited diseases. And actually much progress has been made in this area; over 300 specific genes involved in hereditary diseases have been localized to specific chromosomes and a recently important contribution has been other diseases as mentioned by Senator Domenici.

Mapping genes on the chromosomes of complex organisms and determining the order or sequence in which the chemical units of DNA are arranged represent major challenges, challenges that NIH is prepared to undertake now in coordination with other federal agencies represented here today, as well as with the university community and the biotechnology industry.

In order to assure that all these efforts to characterize the human genome are complementary to each other, the NIH, the Department of HHS, Office of Health and Environmental Research of the Department of Energy and the Biological, Behavioral, and Social Sciences Directorate of the National Science Foundation have discussed and implemented a coordinated effort. Much of these activities will be carried out under the auspices of the Domestic Policy Counsel, the Biotechnology Working Group's Subcommittee on Human Genome, which I chair.

In addition to NIH, OHER, and the BBS, the Environmental Protection Agency, the Food and Drug Administration, and the United States Department of Agriculture are represented. These coordinated efforts will help to ensure that the United States continues to retain its competitive edge worldwide in genetic research and biotechnology.

Characterizing the genomes of a number of complex organisms is a natural outgrowth of all our efforts directed toward understanding biology. At NIH we are already expanding our activities in genomic analysis and other organizations have similar plans. The Domestic Policy Council Subcommittee on the Human Genome provides a productive channel for sharing our research results and for establishing collaborative projects and coordinating future plans.

While we all agree with the intent of S. 1480 to highlight the importance of understanding the genetic basis of living organisms, we do not feel that the bill as originally described represents the optimal route toward attaining these objectives, and we would be happy to discuss details of that remark during the discussion period. Thank you, Mr. Chairman.

[The prepared statement of Dr. Wyngaarden follows:]

STATEMENT OF JAMES B. WYNGAARDEN, M.D.
DIRECTOR, NATIONAL INSTITUTES OF HEALTH
BEFORE THE
SUBCOMMITTEE ON RESEARCH AND DEVELOPMENT
OF THE SENATE COMMITTEE ON
ENERGY AND NATURAL RESOURCES

Mr. Chairman and Members of the Subcommittee:

I am pleased to have this opportunity to tell you about the activities of the National Institutes of Health in mapping the human genome. The National Institutes of Health (NIH) is the preeminent biomedical research organization in the world. This year, NIH is celebrating its centennial with a reaffirmation of its commitment to research, both basic and clinical, research that is dedicated to the improvement of the health of the American people by furthering the diagnosis, treatment and prevention of disease.

Genetics, the science of inheritance, has been a primary research area of the NIH for a large portion of the entire 100 years of its existence.

As you are well aware, we are currently in the midst of an explosion of biological knowledge. This greatly accelerated pace of discovery really started when the genetic material, called deoxyribonucleic acid (DNA) was found, in 1953, to have a double-stranded twisted structure called a double helix in which opposite strands were precisely joined. Inherent in this structure was the basis for passage of genetic information from one generation to the next. For this discovery, Dr. James Watson, an American, along with his British colleague, Dr. Francis Crick, were awarded the Nobel Prize.

Since then, discovery after discovery in the area of genetics have come so rapidly that the term "biological revolution" is often used. Almost all these new findings have come from American scientists supported by NIH. Six additional Nobel prizes have been awarded for work on DNA structure--all to NIH-funded scientists. The Congress of the United States has recognized the importance of such research to the well-being and improved health of the American people and has consistently supported the NIH budget for this work.

The current budget for NIH is $6.2 billion of which about $2 billion is in an area called biotechnology. About one-half of this amount, or $1 billion, is devoted to genetics, DNA research, and the related service base. This field has developed rapidly, as a result of the discovery of a technique known as recombinant DNA technology which permits the snipping of a small piece of DNA from one site in the gene, and its insertion into another--even into the DNA of another different organism, if that is desired. Again this discovery was made by American scientists who also won the Nobel Prize. The use of this technology has not only spawned the new biotechnology industry, able to produce important chemicals and drugs, but has also made it possible to do the project which S. 1480 proposes, to map and eventually to sequence the entire human genome, the complete genetic material of man. The project is actually feasible now, and with further methodological advances will be easier and cheaper in the future.

NIH has long been committed to the support of research leading to a full understanding of the genetics of normal human development and of what goes wrong in human disorders. This work is absolutely indispensable to our mission of acquiring a deep understanding of how biological systems develop and function, and what goes awry in the thousands of diseases that affect mankind. Molecular biology and molecular chemistry are the central themes, the pervasive mechanisms of most of what our scientists do.

In Fiscal Year 1986, NIH provided $300 million of its funds to about 3,000 research projects related to the elucidation of complex genomes, of which about $100 million was related to mapping and sequencing the human genome. Scientists supported by NIH are now engaged in a concerted effort to "map" or pinpoint the specific location of genes on chromosomes, especially those genes responsible for inherited disorders. Researchers have already mapped many genes and have found the approximate locations of the genes for Huntington's disease, Duchenne's muscular dystrophy, retinoblastoma (cancer of the eye in children), some forms of manic-depressive illness, cystic fibrosis, cancer of the colon, and Alzheimer's disease, as well as a number of other disorders. Finding these genes will allow researchers to make copies of them for study, to learn what protein each gene makes, to define the precise mechanism of causation of these disorders, to understand ways to treat disorders that arise from defects in these proteins, and perhaps even to replace defective genes. Mapping genes on the chromosomes of complex organisms and determining the order or sequence in which the chemical units of DNA are arranged represent major challenges, challenges that NIH is prepared to undertake now in coordination with the other Federal agencies represented here today, as well as with the university community and the biotechnology industry.

NIH believes the National Laboratories can play a very substantial role in the program to map the human genome, particularly the Los Alamos National Laboratory. Indeed, it already does so. Let me explain:

It became clear, some time ago, that an organized effort was needed to store, catalog, and distribute the nucleic acid sequence data that were being generated so rapidly. In 1979, Dr. Walter Goad of Los Alamos National Laboratory began a DNA sequence data base as a pilot project. Subsequently, based on his success, NIH established GenBank in 1982. This data base is still developed and prepared for distribution by scientists at the Los Alamos National Laboratory. During the first five years of the contract, $3.6 million has been spent for this effort. During this time, the number of nucleic acid sequences appearing in the literature has increased tenfold and, as efforts to map and sequence the human genome are intensified, the data will multiply very rapidly. We anticipate a possible increase of 16 times the number of sequences determined per year. NIH will soon award the new GenBank contract and provisions for these increased needs have been made.

In order to assure that all these efforts to characterize the human genome (by that I mean to map and then to sequence) are complementary to each other, the NIH of the Department of Health and Human Services (DHHS); the Office of Health and Environmental Research (OHER), Department of Energy (DOE); and the Biological, Behavioral, and Social Sciences Directorate (BBS), of the National Science Foundation (NSF), have implemented a coordinated effort. Currently, there is a group known as the Biotechnology Working Group of the Domestic Policy Council. A subcommittee of this group has been established for the express purpose of coordinating federal activities related to the human genome. In addition to NIH, OHER, and the NSF, the Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), and the United States Department of Agriculture (USDA) are represented. I serve as the Chairman of the Subcommittee on the Human Genome. In this role, I intend to ensure that the project to characterize the human genome is carried out by the scientific organizations most qualified to do the work, is a coordinated effort, and that there is no unnecessary duplication of effort. The scientific and technical skills of researchers throughout the country in Federal, university, and industrial laboratories, as well as at the National Laboratories, must and will be utilized to the maximum, thus assuring that the U.S. continues to retain its competitive edge worldwide in genetics research and biotechnology.

Within the year, two major reports will be published, one by the National Academy of Sciences, and the second by the Office of Technology Assessment. Both of these documents will provide a comprehensive overview of the state-of-the-science and the cost of reaching the next level of technological achievement. Characterizing the genomes of a number of complex organisms is a natural outgrowth of all our efforts directed toward understanding biology. Eventually, technological and methodological improvements will enhance efficiency and reduce the costs of genetic mapping and sequencing. At NIH, we are already expanding our activities in genomic analysis, and other organizations have similar plans. The Domestic Policy Council Subcommittee on the Human Genome provides a productive channel for sharing our research results, for establishing collaborative projects, and for coordinating future plans.

While we agree with the intent of S. 1480 to highlight the importance of understanding the genetic basis of living organisms, we do not feel that the bill describes the optimal route toward attaining these objectives.

Mr. Chairman, members of the Subcommittee, this concludes my prepared remarks. I would be pleased to answer any questions you would like to ask.

Senator **Ford**. Thank you. Dr. Rona.

STATEMENT OF DR. WILLIAM R. GRAHAM, SCIENCE ADVISER TO THE PRESIDENT AND DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY, AS PRESENTED BY DR. THOMAS RONA, DEPUTY DIRECTOR DESIGNATE, OFFICE OF SCIENCE AND TECHNOLOGY POLICY, THE WHITE HOUSE

Dr. **Rona**. Mr. Chairman, thank you for the opportunity to present my views here. I am sitting in for Dr. Graham, who was unavoidably detained. I serve as his Deputy Director for the Office of Science and Technology Policy. My biography is offered for the record.

My colleagues here have discussed the substance of the bill rather, the substance of the human genome problem, mapping problem in far more detail and far more competently than I could have done.

My colleagues on the witness stand have made statements as to the nature of the problem far more competent that I could have done. So instead of trying to duplicate those remarks, I will try to expand on them.

The human genome mapping problem program is an absolutely unique opportunity to us to know ourselves much better and in much greater detail than was ever possible. It was absolutely unheard of or undreamt of as little as 30 years ago. It offers a completely new dimension of human endeavor.

As such, it is extremely likely to attract the interest of all nations, all those who are interested in science, and I am particularly concerned about the fact that this nation, while outstanding in matters of science and technology has a tendency to express also concern about the ethical and social considerations associated with such problems. So I am particularly pleased to see that the policy board has as one of its specific objectives to express interest in the ethical and so-called strategy considerations which are associated with this problem.

I am convinced that eventually as we better know the possible import of this research, we will discover enormous social, human, economic, and possibly even national security impacts. So while we have a certain number of reservations as to the detailed wording of the bill, we fully support its intent.

I will essentially restrict my comments to that pending further discussion.

[The prepared statement of Dr. Graham follows:]

PROPOSED TESTIMONY
OF
WILLIAM R. GRAHAM
SCIENCE ADVISER TO THE PRESIDENT
AND
DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY

BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

2:00 P.M., SEPTEMBER 15, 1987
ROOM SD-366, DIRKSEN SENATE OFFICE BUILDING
WASHINGTON, D.C.

S.1480
DEPARTMENT OF ENERGY NATIONAL LABORATORY
COOPERATIVE RESEARCH INITIATIVE ACT

CHAIRMAN FORD AND MEMBERS OF THE COMMITTEE, IT IS A PLEASURE TO APPEAR BEFORE YOU TODAY TO DISCUSS PROPOSED LEGISLATION S.1480, THE DOE NATIONAL LABORATORY COOPERATIVE RESEARCH INITIATIVES ACT. I AM ENCOURAGED THAT THE CONGRESS IS CONTINUING TO DEMONSTRATE ITS COMMITMENT TO USE OUR STRENGTH IN SCIENCE AND TECHNOLOGY TO PROMOTE THE COMPETITIVE POSITION OF THE UNITED STATES IN A GLOBAL ECONOMIC ENVIRONMENT. THIS LEGISLATION IS EVIDENCE THAT YOUR GOAL IS TO IMPROVE THE DEPARTMENT OF ENERGY NATIONAL LABORATORIES' LINKS TO U.S. UNIVERSITIES AND INDUSTRY IN ORDER TO STREAMLINE THE TRANSFER OF TECHNOLOGY TO THE MARKETPLACE. I COMMEND SENATOR DOMENICI FOR HIS CONTINUING EFFORTS TOWARD THIS END. WHILE I DO NOT ENDORSE ALL THE PROVISIONS CONTAINED IN S.1480, IT IS OBVIOUS THAT WE SHARE A VISION OF USING AMERICAN INGENUITY TO DRIVE A POWERFUL AND VIBRANT ECONOMY AS WELL AS TO PROTECT OUR NATIONAL SECURITY.

BEFORE I ADDRESS EACH TITLE OF THE BILL IN ORDER OF OCCURRENCE, I WOULD LIKE TO MAKE A FEW OBSERVATIONS ABOUT THIS LEGISLATION AND HOW IT FITS WITH OTHER INITIATIVES UNDER DEVELOPMENT WITHIN THE FEDERAL GOVERNMENT.

SCIENCE AND TECHNOLOGY CENTERS:

AS YOU KNOW, THE PRESIDENT HAS SENT CONGRESS A REQUEST TO ESTABLISH WITHIN THE NATIONAL SCIENCE FOUNDATION SCIENCE AND TECHNOLOGY CENTERS DESIGNED TO FORM A COOPERATIVE ASSOCIATION BETWEEN AMERICAN UNIVERSITIES AND INDUSTRY. WE BELIEVE THAT THESE CENTERS CAN BE CATALYSTS FOR APPROPRIATE EXCHANGE THAT WILL ALLOW THE SCIENTISTS AND ENGINEERS WORKING IN ACADEMIA TO TRANSFER IDEAS TO ENTREPRENEURS AND DEVELOPERS IN THE

CORPORATIONS OF AMERICA. IN RETURN, THE TECHNOLOGISTS WORKING IN THE CORPORATE RESEARCH LABORATORIES CAN ASSIST THEIR UNIVERSITY COLLEAGUES BY INSTILLING A SENSE OF PURPOSE AND URGENCY TO THE GOVERNMENT'S BASIC RESEARCH AGENDA.

IN TESTIMONY EARLIER THIS YEAR BEFORE THE HOUSE SPACE, SCIENCE, AND TECHNOLOGY COMMITTEE, I EXPRESSED MY INTENT TO WORK TO SEE THIS CONCEPT EXPANDED IN FUTURE YEARS TO AGENCIES IN ADDITION TO THE NATIONAL SCIENCE FOUNDATION AND TO THE NATION'S FEDERAL LABORATORIES. I BELIEVE THAT S.1480 INDICATES THAT SENATOR DOMENICI AND WE IN THE ADMINISTRATION SHARE MANY OF THE SAME GOALS. YOU MAY BE SURE THAT THE GENERAL CONCEPT OF COOPERATIVE RESEARCH CENTERS FOR THE PURPOSE OF RAPID TRANSFER OF TECHNOLOGY WILL BE SUPPORTED BY THE REAGAN ADMINISTRATION.

TECHNOLOGY TRANSFER:

AS YOU KNOW, THE ADMINISTRATION HAS ALSO SUPPORTED INITIATIVES OF CONGRESS TO IMPROVE TECHNOLOGY TRANSFER BETWEEN OUR UNIVERSITIES, INDUSTRIES AND GOVERNMENT LABORATORIES. IN PARTICULAR WE HAVE APPROVED AUTHORITY FOR THE OPERATORS OF THE GOVERNMENT-OWNED GOVERNMENT-OPERATED (GOGO) LABORATORIES TO ENTER INTO COOPERATIVE R&D AGREEMENTS AND, IN THAT CONTEXT, MAKE SUITABLE AGREEMENTS RELATING TO THE DISPOSITION OF INTELLECTUAL PROPERTY RIGHTS.

EARLIER THIS YEAR, I ASKED THE WHITE HOUSE SCIENCE COUNCIL TO EXAMINE THE PROBLEMS AND THE BENEFITS THAT WOULD RESULT FROM EXPANDING THIS SAME AUTHORITY TO CONTRACTORS OF GOVERNMENT-OWNED CONTRACTOR-OPERATED (GOCO) LABORATORIES. ON BALANCE, THEY FAVORED THIS CHANGE.

HOWEVER, RATHER THAN EFFECT SUCH A POLICY CHANGE ON A PIECEMEAL BASIS ONLY FOR CERTAIN KINDS OF RESEARCH, SUCH AS THOSE CONTAINED WITHIN THIS PROPOSED LEGISLATION, I BELIEVE THAT WE SHOULD STRIVE TO DEVELOP A FEDERAL DATA POLICY FOR ALL GOVERNMENT AGENCIES TAKING INTO CONSIDERATION THEIR INDIVIDUAL EXISTING STATUTORY AND NATIONAL SECURITY RESPONSIBILITIES.

FUNDING ALLOCATIONS:

AS YOU KNOW, THE PRESIDENT HAS SUBMITTED TO CONGRESS A BUDGET FOR FY 1988 INTENDED TO MEET THE GRAMM-RUDMANN-HOLLINGS TARGETS. THIS BUDGET WAS PRODUCED AFTER MUCH DEBATE WITHIN THE EXECUTIVE OFFICE AND EACH COMPONENT WAS EXAMINED IN CAREFUL DETAIL FOR ITS ABSOLUTE NECESSITY. I AM PLEASED TO STATE THAT EVEN AFTER SUCH CAREFUL SCRUTINY, THIS BUDGET CONTAINED A SUBSTANTIAL GROWTH IN THE SCIENCE AND TECHNOLOGY PROGRAMS AND EVEN MADE A COMMITMENT TO DOUBLE THE BUDGET FOR THE NATIONAL SCIENCE FOUNDATION OVER THE NEXT FIVE YEARS. IN TAKING SO BOLD A POSITION, THE PRESIDENT DEMONSTRATED HIS STRONG BELIEF IN THE POWER OF SCIENCE AND TECHNOLOGY TO SUPPORT THE ECONOMIC FUTURE OF THIS NATION.

TODAY I REAFFIRM MY SUPPORT FOR THE GOALS CONTAINED IN THE PRESIDENT'S BUDGET. I COULD NOT, HOWEVER, AGREE TO INCREASE TAXES, REDUCE SPENDING IN OTHER AREAS OF THE BUDGET, OR WITHOUT GOOD REASON TO MOVE FUNDS FROM ONE AREA OF SCIENCE AND TECHNOLOGY TO ANOTHER. I AM LIKEWISE CONCERNED ABOUT THE INCREASING TREND TO BURDEN THE DEPARTMENT OF ENERGY WITH PRESCRIPTIVE LEGISLATION WHICH FORCES IT TO REDUCE FUNDING IN AREAS IT JUDGES IMPORTANT. IN PARTICULAR, THE BASIC ENERGY SCIENCES PROGRAM (WHICH INCLUDES SUBSTANTIAL FUNDS FOR THE NATIONAL LABORATORIES) CURRENTLY SUPPORT SUCH BASIC RESEARCH THAT IS ESSENTIAL TO OUR LONG-TERM COMPETITIVENESS.

WITH YOUR PERMISSION, I WOULD NOW LIKE TO ADDRESS EACH TITLE OF S.1480 INDEPENDENTLY.

TITLE I - HIGH TEMPERATURE SUPERCONDUCTORS:

THE TITLE I PROVISION TO, "ESTABLISH COOPERATIVE RESEARCH CENTERS IN ENABLING TECHNOLOGY FOR SUPERCONDUCTING MATERIALS AND APPLICATIONS AT NATIONAL LABORATORIES WITH APPROPRIATE UNIVERSITY AND PRIVATE INDUSTRY PARTICIPANTS," IS IN CONSONANCE WITH THE OBJECTIVES OF THE PRESIDENT'S EXECUTIVE ORDER 12591, FACILITATING ACCESS TO SCIENCE AND TECHNOLOGY AND, FOR THAT REASON IT IS UNNECESSARY. THE FORMATION OF A COUNCIL FOR RESEARCH ON ENABLING TECHNOLOGIES COMPRISING REPRESENTATIVES FROM GOVERNMENT, UNIVERSITIES, AND INDUSTRY, WHILE LARGELY CONSISTENT WITH THE OBJECTIVES OF THE PRESIDENT'S SUPERCONDUCTIVITY INITIATIVE, MAY BE UNNECESSARY.

AS A RESULT OF THE PRESIDENT'S SUPERCONDUCTIVITY INITIATIVE, A "WISE MEN" ADVISORY GROUP HAS BEEN ESTABLISHED UNDER THE AUSPICES OF THE WHITE HOUSE SCIENCE COUNCIL IN ORDER TO ADVISE THE ADMINISTRATION ON RESEARCH AND COMMERCIALIZATION POLICIES. THE ADVISORY GROUP'S GUIDANCE ROLE IN SETTING GOALS AND STRATEGIES SHOULD PROVIDE AN IMPORTANT IMPETUS TO RAPID COMMERCIALIZATION OF HIGH-TEMPERATURE SUPERCONDUCTOR APPLICATIONS. THE WISE MEN'S ADDITIONAL ROLE -- THAT OF HELPING TO SET GUIDELINES FOR THE RELEASE OF TECHNICAL FINDINGS AND DEVELOPMENTS IS ALSO IMPORTANT TO SUCH COOPERATIVE ENDEAVORS -- WILL HELP TO ENSURE THAT THOSE DIRECTLY INVOLVED IN THESE COOPERATIVE VENTURES RETAIN SOME MEASURE OF CONTROL OVER THE DISSEMINATION OF FINDINGS. OTHERWISE SUCH DISSEMINATION COULD DAMAGE THE COMMERCIAL VIABILITY OF THE NEW TECHNOLOGY. FINALLY, IN THIS REGARD, I WOULD LIKE TO NOTE THE RECENT FORMATION OF AN INDEPENDENT "COUNCIL ON SUPERCONDUCITIVITY FOR AMERICAN COMPETITIVENESS," CHAIRED BY FORMER SCIENCE ADVISER DR. GEORGE KEYWORTH.

OVERALL, THE PROPOSED LEGISLATION RELATING TO SUPERCONDUCTIVITY DUPLICATES THE AUTHORITY GIVEN BY THE PRESIDENT TO THE DEPARTMENT OF ENERGY AND OTHER AGENCIES. YET ANOTHER COUNCIL COULD CONFUSE AUTHORITY FOR THIS IMPORTANT NATIONAL OPPORTUNITY. IN THE SUPERCONDUCTIVITY INITIATIVE, THE PRESIDENT FURTHER ENCOURAGED FEDERAL AGENCIES TO REALLOCATE FY 1987 FUNDS INTO

SUPERCONDUCTIVITY BASIC RESEARCH, AND TO PLACE HIGH PRIORITY FOR THIS AREA IN FY 1988 FUNDING AND FY 1989 PLANNING. MORE LEGISLATION IN THIS AREA IS UNNCESSARY.

TITLE II - MAPPING THE HUMAN GENOME:

DEVELOPMENT OF AN ORDERED SET OF DNA FRAGMENTS TO FORM A PHYSICAL MAP AND TO SEQUENCE DNA IS UNDOUBTEDLY A WORTHWHILE ENDEAVOR. ACCESS TO BOTH A SET OF FRAGMENTS AND A COMPUTERIZED DATABASE OF HUMAN DNA SEQUENCES WILL RELIEVE RESEARCHERS OF REPETITIVE TASKS AND FREE THEM FOR MORE CREATIVE WORK. FURTHER BENEFITS WILL ACCRUE AS ADDITIONAL TOOLS BECOME AVAILABLE TO ANALYZE DNA SEQUENCES AND TO PREDICT THE FUNCTIONS OF THE SUBSTANCES FOR WHICH THEY CODE.

COST HAS BEEN THE PRIMARY BARRIER IN DEVELOPING A COMPLETE GENETIC MAP AND SEQUENCE OF DNA. FOR THAT REASON, THE DEPARTMENT COMPETITIVENESS," CHAIRED BY FORMER SCIENCE ADVISER DR. GEORGE KEYWORTH.

THE DEPARTMENT IS LAYING OUT A PROGRAM PLAN TO DESCRIBE ITS MANAGEMENT APPROACH FOR DEVELOPING THESE TECHNOLOGIES. THAT APPROACH WOULD EMPLOY THE MULTIDISCIPLINARY CAPABILITIES OF THE DOE NATIONAL LABORATORIES AND DRAW ON OTHER FEDERAL AGENCIES, THE ACADEMIC COMMUNITY, AND THE PRIVATE SECTOR. IN KEEPING WITH GOOD PROGRAM PRACTICE, AND CONSISTENT WITH THE PRESIDENT'S COMPETITIVENESS INITIATIVE, THE PROGRAM PLAN WILL IDENTIFY OPPORTUNITIES FOR PRIVATE SECTOR INVOLVEMENT IN PROGRAM PLANNING, EVALUATION, AND EXECUTION, SO AS TO ENSURE THE MOST EFFECTIVE TRANSFER OF TECHNOLOGY TO THE PRIVATE SECTOR. TECHNOLOGY DEVELOPED WITHIN THE HUMAN GENOME INITIATIVE CAN BE TRANSFERRED TO THE PRIVATE SECTOR VERY EFFECTIVELY USING EXISTING MECHANISMS.

THE SUCCESS OF THE HUMAN GENOME INITIATIVE WILL BE VALUABLE NOT ONLY TO DOE IN ITS RESPONSIBILITIES FOR ENERGY-RELATED HEALTH AND ENVIRONMENT EFFECTS, BUT TO NUMEROUS INVESTIGATORS SUPPORTED BY THE NATIONAL INSTITUTES OF HEALTH, MANY OF WHOM NOW MUST CARRY OUT MAPPING AND SEQUENCING PROCEDURES. NIH CONTINUES TO SUPPORT RESEARCH ON GENEICS OF HUMAN DEVELOPMENT AND IS ENGAGED IN AN EFFORT TO LOCATE THOSE GENES RESPONSIBILE FOR HUMAN DISABILITIES. NIH FUNDS ABOUT 3,000 RESEARCH PROJECTS RELATED TO GENE ELUCIDATION AND WILL CONTINUE TO PROVIDE SUPOORT FOR THESE AND OTHER HUMAN GENOME MAPPING PROJECTS.

THE THREE AGENCIES INVOLVED IN RESEARCH RELATED TO THE HUMAN GENOME INITITATIVE--DOE, NIH, AND NSF--HISTORICALLY HAVE HAD COMPLEMENTARY ROLES. COORDINATION AMONG AGENCIES ON THIS INITIATIVE HAS BEEN FACILITATED BY THE EXECUTIVE OFFICE OF THE PRESIDENT, AND MECHANISMS EXIST WITHIN THE OFFICE TO CONTINUE COORDINATION OF THESE COMPLEMENTARY EFFORTS AND TO INVOLVE THE PRIVATE SECTOR. PRIVATE SECTOR INVOLVEMENT IS IMPORTANT TO COST-EFFECTIVE EXECUTION OF THE INITIATIVE AND IS CRITICAL TO EFFECTIVE TECHNOLOGY TRANSFER.

THE COORDINATION BETWEEN ALL THE AGENCIES TO IDENTIFY PROMISING TECHNIQUES SUITABLE FOR EVALUATION AS PART OF THE TECHNOLOGY DEVELOPMENT PROGRAM AND TO IDENTIFY NEEDS OF RESEARCHERS WILL CONTRIBUTE TO THE SUCCESS OF THE INITIATIVE. IN ADDITION TO THE NIH ACTIVITIES REFERED TO ABOVE, NIH IS EXPECTED TO CONTINUE TO PLAY AN IMPORTANT ROLE IN SUPPORTING THE DNA-SEQUENCE DATABASE, WHICH IS KNOWN AS GENBANK, ALONG WITH NSF AND DOE AND IN SUPPORTING DEVELOPMENT OF A SYSTEM FOR MAKING THE RESULTS OF THE MAPPING EFFORT AVAILABLE TO ALL INVESTIGATORS. COORDINATION WITH THE NATIONAL SCIENCE FOUNDATION WILL ENHANCE DEVELOPMENT OF MATHEMATICAL TECHNIQUES FOR ANALYZING DNA SEQUENCES AND FOR DEVELOPING TECHNIQUES TO PREDICT THE FUNCTIONS OF A PROTEIN FROM ITS DNA SEQUENCE.

IN SUMMARY, THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY SUPPORTS THE HUMAN GENOME INITIATIVE AS PROPOSED IN THE ADMINISTRATION'S FY 1988 BUDGET BECAUSE OF ITS POTENTIAL FOR IMPROVING THE COMPETITIVENESS OF AMERICAN INDUSTRY AND ADVANCING SCIENCE IN AREAS THAT DIRECTLY AFFECT OUR LIVES. HOWEVER, WE DO NOT BELIEVE THAT ADDITIONAL AUTHORIZING LEGISLATION IS NEEDED TO CARRY OUT THIS INITIATIVE.

TITLE III - SEMICONDUCTOR INITIATIVE:

IN DISCUSSING TITLE III OF THE BILL, LET ME BEGIN BY STATING THAT I AM IN FULL AGREEMENT WITH SENATOR DOMENICI AS TO THE CRITICAL IMPORTANCE OF THE SEMICONDUCTOR INDUSTRY TO OUR ECONOMIC AND NATIONAL SECURITY. TWO STUDIES CARRIED OUT FOR THE GOVERNMENT--BY THE DEFENSE SCIENCE BOARD AND THE WHITE HOUSE SCIENCE COUNCIL--CLEARLY SUPPORT THIS NOTION. THE CRITICAL QUESTION CONCERNING THE COMPETITIVENESS OF THE SEMICONDUCTOR INDUSTRY, ESPECIALLY WITH RESPECT TO MANUFACTURING TECHNOLOGY, WHAT IS THE APPROPRIATE ROLE FOR THE GOVERNMENT. THIS ISSUE IS NOW UNDER REVIEW WITHIN THE ADMINISTRATION.

TITLE III OF THE BILL FOCUSES ON A "SEMICONDUCTOR TECHNOLOGY MANUFACTURING EXCELLENCE INITIATIVE," WHICH TRACKS IN MANY WAYS WITH SEMATECH, THE RECENTLY FORMED INDUSTRY CONSORTIUM TO DEVELOP AND IMPROVE U.S. SEMICONDUCTOR MANUFACTURING TOOLS AND METHODS. I AND MY STAFF HAVE SPENT CONSIDERABLE TIME WITH THE SEMATECH DEVELOPERS, BOTH IN WASHINGTON AND AT SEVERAL WORKSHOPS THEY HAVE SPONSORED WITH INDUSTRY AND THE NATIONAL LABORATORIES. AS A RESULT OF THE MANY DISCUSSIONS WE HAVE HAD, I BELIEVE THAT IT IS A GOOD IDEA--ONE THAT WILL HELP THE INDUSTRY IN AN AREA WHERE JAPANESE CORPORATIONS HAVE PROVED SUPERIOR--THAT IS IN THE AREA OF MANUFACTURING TECHNOLOGY. IN THIS REGARD AND BECAUSE OF THE IMPORTANT ISSUE OF GOVERNMENT FUNDING, SEMATECH HAS BEEN GIVEN CONSIDERABLE ATTENTION. HOWEVER, AS POINTED OUT BY THE WHITE HOUSE SCIENCE COUNCIL AND BY MANY WITHIN THE SEMICONDUCTOR INDUSTRY, NO SINGLE ACTION CAN SUCCESSFULLY ADDRESS ALL THE FACTORS THAT MUST BE REMEDIED TO IMPROVE THE INDUSTRY'S LONG-TERM INTERNATIONAL COMPETITIVENESS.

IT IS THE LONG-STANDING POLICY OF THE FEDERAL GOVERNMENT TO SUPPORT BASIC RESEARCH IN ENABLING TECHNOLOGIES. THE ADMINISTRATION IS CONSIDERING WHETHER ADDITIONAL MEASURES SHOULD BE TAKEN TO PROMOTE ENABLING TECHNOLOGIES IN THE SEMICONDUCTOR AREA. THE SEMATECH INITIATIVE, WHILE IMPORTANT, GOES BEYOND BASIC RESEARCH INTO THE APPLIED AREA. IN MY JUDGMENT IT IS NOT APPROPRIATE FOR NON-DEFENSE AGENCIES OF THE FEDERAL GOVERNMENT TO PROVIDE SUPPORT BEYOND THE LEVEL OF BASIC RESEARCH TO SPECIFIC COMMERCIAL SECTORS OF THE ECONOMY. IT MAY BE, HOWEVER, APPROPRIATE FOR THE DEPARTMENT OF DEFENSE TO SUPPORT SEMATECH OR SIMILAR INITIATIVES THAT MEET DOD REQUIREMENTS TO ENSURE OUR NATIONAL SECURITY.

I BELIEVE DOD HAS EARMARKED $50 MILLION IN ITS FY-88 BUDGET FOR MANUFACTURING METHODS FOR SEMICONDUCTORS USED IN WEAONS SYSTEMS. I AM CONCERNED, HOWEVER, WITH ADDITIONAL MONEY BEING APPROPRIATED TO THE DEPARTMENT OF ENERGY TO BE USED FOR SEMATECH, UNLESS IT CAN BE CLEARLY DEMONSTRATED THAT SUCH FUNDS WILL SUPPORT THE NATIONAL SECURITY MISSION OF THE DOE, AS IS THE CASE WITH SANDIA NATIONAL LABORATORY'S RADIATION-HARDENED SEMICONDUCTOR PROGRAM. I WILL DEFER, HOWEVER, TO DOE, WITH RESPECT TO WHETHER THAT DEPARTMENT BELIEVES IT NEEDS ADDITIONAL FUNDS TO SUPPORT DEVELOPMENT OF ENABLING TECHNOLOGIES THROUGH THE SEMATECH CONSORTIUM.

S.1480 EMPHASIZES THE ROLE OF THE DOE NATIONAL LABORATORIES, CONCERNING A SEMICONDUCTOR MANUFACTURING INITIATIVE. THE BILL STATES THAT AN ESSENTIAL PART OF EACH DOE NATIONAL LABORATORY'S MISSION WILL BE PARTICIPATION IN R&D PROJECTS IN CONJUNCTION WITH DOE AND INDUSTRY CONSORTIA. I BELIEVE THE NATIONAL LABORATORIES ARE ALREADY PLAYING A CONSTRUCTIVE ROLE IN FURTHERING OUR COMPETITIVENESS IN THE SEMICONDUCTOR AREA. CURRENTLY THERE ARE A NUMBER OF COOPERATIVE PROGRAMS WITH INDUSTRY. DOE HAS JUST INITIATED AN INDUSTRY-UNIVERSITY PROGRAM ON MATERIALS PROCESSING AT THE OAK RIDGE NATIONAL LABORATORY. WHILE I FAVOR THE NATIONAL LABORATORIES BECOMING MORE INVOLVED IN BASIC RESEARCH THAT COULD BENEFIT OUR INDUSTRIAL COMPETITIVENESS, I AM CONCERNED THAT SUCH ACTIVITY NOT BE AT THE EXPENSE OF OTHER MISSION REQUIREMENTS. EXCHANGE OF INFORMATION BETWEEN THE NATIONAL LABORATORIES AND INDUSTRY SHOULD BE ENCOURAGED, AND SPECIAL PROGRAMS IN THE LABORATORIES AIMED AT COMMERCIAL OBJECTIVES SHOULD BE CAREFULLY REVIEWED, SO AS NOT TO TAX THEIR MISSION REQUIREMENTS. FURTHERMORE, BECAUSE THE INDUSTRY HAS MUCH TO GAIN FROM COOPERATIVE PROGRAMS WITH THE NATIONAL LABORATORIES, I BELIEVE, CONSISTENT WITH THE PROPOSED LANGUAGE, THAT INDUSTRY SHOULD BEAR PART OF THE COSTS. WITH RESPECT TO THIS POINT THE LABORATORIES MUST ENDEAVOR TO AVOID GETTING IN THE WAY OF THE PRIVATE SECTOR IN ITS DEVELOPMENT AND COMMERCIALIZATION ACTIVITIES.

TITLE IV - ENTREPRENEURIAL STUDIES:

I BELIEVE THAT IT IS IMPORTANT FOR UNIVERSITIES TO ENCOURAGE PROFESSORS TO BE ENTREPRENEURS AND TO DEVELOP PROGRAMS WHEREBY STUDENTS ARE ENCOURAGED TO BECOME ENTREPRENEURS. I AM CONCERNED, HOWEVER, ABOUT THE NOTION OF THE FEDERAL GOVERNMENT PRESCRIBING TO THE UNIVERSITIES HOW THEY SHOULD ACCOMPLISH THIS GOAL. IF ONE EXAMINES THE RESEARCH PARKS THAT CONTINUE TO SPRING UP AROUND OUR BEST RESEARCH UNIVERSITIES, ONE HAS TO BELIEVE THAT THEY KNOW SOMETHING ABOUT THIS PROCESS.

S.1480 NOT ONLY PRESCRIBES A STRONG ASSOCIATION BETWEEN ENTREPRENEURS AND THE DEPARTMENT OF ENERGY LABORATORIES, BUT IT ALSO PRESCRIBES THE CURRICULUM FOR OUR PUBLIC OR PRIVATE UNIVERSITIES AND HOLDS THAT A MASTER'S DEGREE IN ENTREPRENEURIAL STUDIES SHALL BE PROOF OF SUCCESS. I CANNOT CONCEIVE OF THE FEDERAL GOVERNMENT ADVISING UNIVERSITIES HOW TO EDUCATE FUTURE ENTREPRENEURS IN WAYS TO BE ENTREPRENEURIAL. THIS SURELY SHOULD BE LEFT TO THE REAL EXPERTS--THOSE IN U.S. INDUSTRY. I THEREFORE RECOMMEND DELETION OF TITLE IV FROM S.1480.

FINAL REMARKS:

I HAVE TRIED TO MAKE MY COMMENTS AS CONSTRUCTIVE AS POSSIBLE, AS I HAVE FOUND MANY AREAS OF AGREEMENT WITHIN THE FIRST THREE TITLES. I LOOK FORWARD TO WORKING WITH SENATOR DOMENICI AND THIS SUBCOMMITTEE TOWARD THE IMPORTANT GOALS WE SHARE.

MR. CHAIRMAN, I AM NOW PREPARED TO ANSWER QUESTIONS.

Senator FORD. Mr. Beringer.

STATEMENT OF BARRY BERINGER, ASSOCIATE UNDER SECRETARY FOR ECONOMIC AFFAIRS, DEPARTMENT OF COMMERCE, ACCOMPANIED BY NORMAN LATKER

Mr. BERINGER. Thank you, Mr. Chairman. I appreciate the invitation to testify today on the management of technology resulting from federally funded research and development.

I am accompanied today by Norman Latker, the Director of the Division of Federal Technology Management.

On this, the 200th anniversary of the signing of our Constitution, it is especially appropriate that we should discuss the patent clause in Article One, Section 8 of that document, which reads, "The Congress shall have the power to promote the progress of science and the useful arts by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries."

Several decades later, Abraham Lincoln, himself an inventor, succinctly interpreted the meaning of this clause when he noted that "The patent system added the fuel of interest to the fire of genius."

We at the Commerce Department have been attempting to bring the fuel of interest to the fire of genius which resides at our federal laboratories and universities, which undertake federally funded research. And thus the Department has been significantly involved in the development of policy that guides the management of federally created technology.

Among our most significant assignments is the responsibility for the regulations that regulate the Bayh-Dole Act of 1980, Public Law 96-517 as amended by Public Law 98-620, the Trademark Clarification Act of 1984.

The March 18, 1987 issuance of these regulations requires all federal agencies to use a standard patent rights clause that gives nonprofit and small business contractors the first option to ownership, to patentable results of their federally funded research.

In 1983, the president extended this treatment of the aforesaid non-profit and small business contractors to all other federal contractors and restated this policy in his Executive Order 12591, signed on April 10, 1987. This policy has been evolving over at least a decade, and it is important the the committee be aware of factors that led to its development.

American industry is encountering increasingly tough international competition, caused in part by a world wide explosion in new technology. U.S. trade deficits are partially explained by new foreign technology, capturing markets previously dominated by the United States.

This challenge has called for increased efforts to deliver American inventions, whether publicly or privately created to the marketplace as a source for new businesses and jobs. The U.S. has been investing $110 billion annually in research and development; $55 billion is federally funded, the other half privately funded. Of the 120 patent applications filed annually at the Patent and Trademark office, less than 3,000 cover federally sponsored research. The remainder are the result of private sector R & D, including a growing percent coming from foreign sources which recently passed 46 percent.

These facts have produced strong Administration resolve to increase U.S. commercialization of federally generated products and processes. Under past policies, ownership of federal sponsored technology was often separated from the R & D organization that created the technology, putting it in the hands of centralized federal managers, who did not have the background to judge its value.

Loss of the creator as the owner-advocate made it difficult to continue the complex process of delivering technology to the marketplace, or as Lincoln might have said, "The fuel of interest was separated from the fire of genius" of our federal research scientists. We believe that a key element in increasing the commercialization of federal R & D results is to decentralize technology management to the creating organization.

This objective often achieved by the standard clause implementing PL 96-517. The right of ownership to technology in general brings with it incentives to use resources to evaluate new technology and determine whether it should be published, patented, copyrighted, held in confidence, trademarked or some combination of these actions.

The possibility of income, outside risk capital, and royalty return produced by ownership have already prompted federally funded universities and their publication oriented employe inventors to employ technology managers to identify new patentable technologies, and to assume the complex responsibility of bringing them to the marketplace.

The policies as set forth in the previously mentioned laws and presidential directives are already bearing considerable fruit. In an April 1, 1987 report the General Accounting Office noted, "Increased reporting of inventions by universities and small businesses, increased licensing of inventions by non-profit contractors and small businesses, increased bidding on government contracts by small businesses and increased willingness of business to enter into cooperative R & D arrangements with universities that receive federal funds."

Establishing the incentives of ownership at the time of contracting are very important because intellectual property rights must be identified and sometimes licensed that justify the investment of private risk funding in most technologies.

Failure to establish such rights on a timely basis in potential marketable products by a publicly funded creating organization greatly diminished possible private sector marketing of the product. Public Laws 96-517, 98-620 and the President's patent policy memorandum of February 18, 1983 combined to give universities, small business, and to the extent permitted by law all of other contractors the first right of ownership to patentable inventions made with federal funds.

Public Law 99-502, the Federal Technology Transfer Act of 1986 also extends the principle of decentralized management to government operated laboratories by permitting federal agencies to delegate the management of patentable laboratory technology to the laboratory director.

The Department of Commerce believes that the success of decentralized management of technology is important to many states that are planning economic growth around R & D assets such as universities which are now cooperating with the private sector.

Under Public Law 99-502, federal laboratories can now be included in this asset base. We believe that the pooling of federal, state, university and private sector resources through decentralized management is essential if we are to maintain our technological leadership in the world.

In closing, Mr. Chairman, I want to make an observation that we at Commerce have made on a number of occasions.

Many people worry whether we are losing our competitive edge in developing new technology. Only recently have people come to understand how well we manage what we create, may be just as important as our ability to create. And by "we", I do not mean just the federal government. American businesses are starting to be a lot more careful about protecting their interests, and the federal government is becoming a lot more careful in developing policies that ensure that inventions and finances reach the marketplace.

We are all starting to understand the importance of technology management and the committee's concern and attention to this important but complex subject is indeed gratifying and appreciated.

[The prepared statement of Mr. Beringer follows:]

STATEMENT OF
MR. BARRY BERINGER
ASSOCIATE UNDER SECRETARY FOR ECONOMIC AFFAIRS
U. S. DEPARTMENT OF COMMERCE
BEFORE THE
COMMITTEE ON ENERGY AND NATURAL RESOURCES
ON
SEPTEMBER 17, 1987

Thank you for your invitation to testify on the management of technology resulting from federally-funded research and development. I am accompanied today by Norman Latker, the Director of the Division of Federal Technology Management.

In order to meet a number of executive and legislative mandates, the Department has been significantly involved in the development of the policy that guides the management of federally created technology. Among our most significant assignments is responsibility for the regulations that implement the Bayh-Dole Act of 1980, P.L. 96-517 as amended by P.L. 98-620, "The Trademark Clarification Act of 1984." The March 18, 1987 issuance of these regulations requires all federal agencies to use a standard patent rights clause that gives nonprofit and small business contractors the first option to ownership to the patentable results of their federally-funded research. Deviation from use of the standard rights clause when contracting with these performers, or altering the conditions attached to ownership, is permitted in narrowly defined categories dictated by the law and its legislative history.

In 1983 the President extended the treatment afforded nonprofit and small business contractors to all other federal contractors and restated this policy in Executive Order 12591.

This policy has been evolving over at least the last decade, and it is important that the committee be aware of the factors that have led to its development.

American industry is encountering increasingly tough international competition, caused in part by a worldwide explosion in new technology. U.S. trade deficits are partially explained by new foreign technology capturing markets previously dominated by the U.S.

This challenge has called for increased efforts to deliver American inventions, whether publicly or privately created, to the marketplace as a source for new businesses and jobs.

The U.S. has been investing 110 billion dollars annually in R&D. Fifty-five billion is federally-funded; the other half private. The magnitude of the federal investment raises two questions: Does free access to federally-funded research subsidize foreign competition? Does it deliver a fair return?

The first question has not been answered conclusively, but many believe that American industry should have, at the very least, first option to the practical results of such research--while at the same time preserving open scientific communication.

As to the second question, facts suggest that we could get more from federal investment in R&D. For example, approximately 120,000 patent applications are filed annually in the Patent and Trademark Office. Of these, less than 3,000 cover federally sponsored research. The remainder are the result of private sector R&D--including a growing percent coming from foreign sources, which recently passed 46 percent. These facts have produced strong Administration resolve to increase U.S. commercialization of federally generated products and processes.

Under past policies, ownership of technology was often separated from the R&D organization that created the technology, putting it in the hands of federal managers who did not have the background to judge its value. Loss of the creator as the owner-advocate made it difficult to continue the complex process of delivering technology to the marketplace.

Commerce believes that a key element in increasing the commercialization of federal R&D results is to decentralize technology management to the creating organization. This objective is achieved by the standard clause implementing P.L. 96-517. The right of ownership to technology in general brings with it incentives to use resources to evaluate new technology and determine whether it should be published, patented, copyrighted, held in confidence, trademarked or some combination of these actions. The possibility of income, outside risk capital and royalty return produced by ownership have already prompted federally-funded universities and their publication oriented employee-inventors, to employ technology managers to identify new patentable technologies and to assume the complex responsibility of bringing them to the marketplace.

This activity is noted in an April 1, 1987 General Accounting Office (GAO) report which indicates that there has been:

a. increased invention reporting by nonprofit contractors and small businesses;

b. increased licensing of inventions by nonprofit contractors and small businesses; and

c. increased bidding on government contracts by small business contractors.

Further, as GAO's report pointed out "since the private sector now knows that universities can take title to federally-funded inventions, they are no longer concerned that their research efforts could be `contaminated' by federal funding with the possibility that a federal agency could assert title rights to resulting inventions."

Accordingly, the funding of cooperative arrangements between universities receiving federal R&D funds and industry has grown 74 percent from $277 million in FY 1980 to $482 million in FY 1985 (in constant dollars). The GAO report also points out that while the influence of the The Federal Technology Transfer Act of 1986 alone on competitiveness is difficult to quantify, the overall effect of the change in federal policy has been positive. These facts lead us to believe that the Act has succeeded in fostering the establishment of R&D cooperative agreements which in turn lead to commercialization of federally-funded inventions.

The positive impact of the Act on commercialization has also been confirmed in a July, 1986 report published by the

Association of American Universities (AAU) entitled "Trends in Technology Transfer at Universities."

Establishing the incentives of ownership at the time of contracting are very important because intellectual property rights must be identified and sometimes licensed to justify the investment of private risk funding in most technologies. Failure to establish such rights on a timely basis in a potential marketable product by a publicly funded creating organization greatly diminishes possible private sector marketing of this product.

John Preston, the Director of Technology Licensing at MIT recently testified to the importance of this right in connection with a joint venture he successfully negotiated to develop superconductor technology, which had emerged from a federally-funded program.

Public Laws 96-517, 98-620 and the President's patent policy memorandum of February 18, 1983 combine to give universities, small businesses, and, to the extent permitted by law, all other contractors the first right of ownership to patentable inventions made with federal funds. Public Law 99-502 also extends the principle of decentralized management to government operated laboratories by permitting federal agencies to delegate the management of patentable laboratory technology to the laboratory director.

The Department of Commerce believes that the success of decentralized management of technology is important to the many states that are planning economic growth around R&D assets such as universities which are now cooperating with the private sector. Under P.L. 99-502, federal laboratories can now be included in this asset base. We believe that the pooling of federal, state, university, and private sector resources through decentralized management is essential if we are to maintain technological leadership in the world.

Though the laws and memorandum I referred to are limited to patentable inventions, the President's Executive Order 12591 directs all federal agencies to assist the Office of Federal Procurement Policy in developing a new policy which would extend contractor rights to the nonpatentable results of federally-funded research such as technical data and software made under federal contracts. This initiative is directed to creating an incentive to commercialize ideas that cannot be protected by patent but are, nevertheless, of commercial value.

Good progress has been made in fostering the commercialization of federally-funded technology by agencies implementing P.L. 96-517 and 98-620. Commerce believes that the vigorous implementation of the President's recent Executive Order No. 12591 could lead to even better results. A 55 billion dollar investment demands that we search for the best ways to make it pay off.

Senator FORD. Thank you. I have a couple questions here and I have some questions for the record and ask that you respond to those in a timely manner.

As I understand it, none on this panel feel that legislation is necessary to carry out the human genome initiative. If that is true then, if I recognize what you have said, in your opinion what Federal agency should take the lead in this initiative? And Dr. Rona, I will let you start.

Dr. RONA. The current position is that the NIH is funded for very substantial amounts of research related to this problem. I do not have figures exactly. But I am sure that Dr. Wyngaarden will have it.

The Department of Energy is funded to the extent of $12 million. And their focus is to develop mostly the technology, which is associated with the program.

So we feel that in this particular instance DOE should have the leadership and continue doing so. Other agencies should get involved, in particular our own office.

Senator FORD. Mr. Beringer?

Mr. BERINGER. I would defer to OST and the other agencies here on that question.

Senator FORD. That is a good political answer. Thank you. Dr. Decker?

Dr. DECKER. To me, the question of a lead agency is not so terribly important, I think really the important issue here is that the agencies involved work together in a coordinated way to get the job done.

And I think that we are doing that now, and we have a good mechanism for doing so.

Senator FORD. Dr. Wyngaarden?

Dr. WYNGAARDEN. I agree with that. I think the coordination is all important, and how fast we can move in this field collectively among our several agencies, it is really a matter of resources.

I would suggest that a somewhat modified subcommittee on human genome might be considered. For example, I think the idea of a national policy board has great merit.

And one way to approach this might be to reorganize and perhaps expand that subcommittee on the human genome to include additional private sector and academic representation.

Senator DOMENICI. What is that a subcommittee of?

Dr. WYNGAARDEN. It is a subcommittee of the Biotechnology Working Group, which is under the Domestic Policy Council.

And that is a subcommittee that presently exists on the human genome, and it is one that brings our agencies together in coordinating information and preparing activities.

Senator DOMENICI. Is it statutorily created?

Dr. WYNGAARDEN. No.

Senator DOMENICI. So it does not have to be there next month, if somebody in the White House does not want it?

Dr. WYNGAARDEN. Well, that is true. But it could be statutorily created as a national policy board, utilizing the same kinds of people, plus some academic representation.

I was going to suggest, just for purposes of suggestion, perhaps four, four, and four. Four from the agency heads, four from the academic world, and four from the industrial sector, including at least one from small business. That would get virtually all groups represented.

Senator **Ford**. Dr. Rona, let me ask. If this project were to remain just as it is, how long would it take it to be complete?

Dr. **Rona**. I do not have good information on this one. I would much rather defer to Dr. Decker on that one.

Senator **Ford**. Dr. Decker, you have just been deferred to. Mr. Beringer is good and Rona picked it up, so we are going to wind up, it is all going to be down here in a minute.

[Laughter.]

Dr. **Decker**. Well, Mr. Chairman, if they all defer, I will answer the question.

Senator **Ford**. Well, we will just disband the rest of the hearing then, because we know where we are going. Dr. Decker.

Dr. **Decker**. I think that the first phase of the initiative that we have talked about, in terms of developing the required technologies, doing the computer work that needs to be done to put the kind of database and computer analysis activity in place and so forth, is probably a five-year program.

Senator **Ford**. Dr. Wyngaarden, what is your estimate of completion, if it stays on the same track?

Dr. **Wyngaarden**. Maybe I can expand on that answer just a bit. We had a meeting with the Directors Advisory Committee on this field, this project some time ago, and we identified four major sequential objectives.

The first was to improve the information handling of genetic sequence data, because it is developing so rapidly that existing data banks are overloaded.

Steps have been taken to accomplish that, and the National Library of Medicine has put out a request for additional applications to address the science base of that area.

The next had to do with methods in general. These range all the way from improving the purification of DNA and chromosome, chromosome fragments, to chromosome separations and even automation. And we are also intensifying that effort.

The third is the mapping of the human chromosome by genetic and physical approaches. The genetic map is probably doable within a few additional years. And the cost for that is estimated in the range of $20 million or $30 million.

The sequencing itself of the entire human genome is a very large project. It is feasible now, but it would be very expensive, because the present cost is running about $1 per base.

Senator **Ford**. How much?

Dr. **Wyngaarden**. About $1 per base. There are 3.5 billion bases involved, and there is a lot of overlap of segments that would be necessary.

So something between $3.5 billion and $6 billion would be required, if that were approached today. Now that cost is coming down as methods are improved. Others are better able than I to estimate what the cost may reach, and how soon.

But that has been estimated to be a project of many years, perhaps 10 years to accomplish that, even if we made an all-out effort, starting now. So those are some rough, very rough approximations.

Senator **Ford**. Let me ask one question then to all four of you, that might be able to get a yes or no out of.

Do you believe the passage of S. 1480 would speed up the process by creating the consortia and the board? Dr. Decker?

Dr. **Decker**. I am not quite sure how to answer.

Senator **Ford**. You can say, I do not know. Or I forgot.

[Laughter.]

Dr. **Decker**. Given where we are right now, I am not sure that the consortium would. But I would want to give that some more thought.

Senator **Ford**. Dr. Wyngaarden, can you give us some kind of judgment?

Dr. **Wyngaarden**. I agree with Dr. Decker. But I think that expanding the mechanism in the manner I mentioned a few minutes ago would be an asset.

Senator **Ford**. Dr. Rona?

Dr. **Rona**. I am sure that the mere introduction of the bill already stimulated a lot of thinking. So in that sense, it was extremely useful.

Now, I would suggest that perhaps a reexamination of the wording would make it more easy to answer the question.

Senator **Ford**. Dr. Beringer?

Mr. **Beringer**. The goal of the bill of bringing private sector involvement, the goal of the board, I think, is a very, very worthwhile goal.

We think that can be best accomplished by forming partnerships with private industry, and I think the bill helps to stimulate that.

Senator **Ford**. Let me ask this, Dr. Wyngaarden. You state in your testimony that S. 1480 is not the optimal route toward obtaining the objectives and goals of the genome initiative.

You started in some manner to answer some of those things. What in your mind is the optimal route?

Dr. **Wyngaarden**. Well, I think that the points I made about the composition of the national policy board would be one place to start.

And I do not personally think that we need a single dominant agency in this. I think the key word is collaboration among the agencies. And I think that could be achieved through the creation of that kind of national policy board.

Senator **Ford**. There is always a fear on the part of those of us who appropriate, authorize and appropriate the funds that everybody has got their own little corner, and they are doing their own little thing.

And sometimes we do not, we are not transferring knowledge, we are not sitting down and cooperating. And it may be just a matter of imagery of how you are perceived.

But somehow or another, until there is a better way of doing it, I have the distinct feeling that we ought to have some policy-setting mechanism in order to help push it along and then also, for lack of a better word, lobby for additional funds to go ahead and proceed as new technologies arrive, state-of-the-art, to move to the, you say three billion items a while ago?

At $1, so we are talking about, you are overloading your computers, you need to find some other things. So you would have somebody to plead your case for you from some fields that would be very helpful, I think, here on the Hill.

Dr. **Wyngaarden**. Yes, that is true. But it is also already happening, as Senator Pepper has introduced a bill dealing with the matter of biotechnology information, and would assign a major responsibility to the National Library of Medicine for that.

The House bill on the NIH budget for next year includes $30 million for genetic mapping. I do not know whether that will ultimately be passed by the Senate and the conference, then the President.

But that does represent a major interest of the House Committee in that project. So support has been very good.

Senator **Ford**. There will be some other questions I have that I will submit to you in writing and ask for you to answer them in a timely fashion.

Senator Domenici?

Senator **Domenici**. Thank you very much, Mr. Chairman. Let me—Dr. Wyngaarden, let me just talk with you a little bit.

First of all, let me see if this is correct. While the NIH is intimately and successfully involved in gene mapping and selective sequencing as part of its program, there is no national policy that I am aware of, correct me if I am wrong, that says the United States of America should, just as simple as this, as expeditiously as possible, map the entire human genome. Is there?

Dr. **Wyngaarden**. Not that I am aware of. No, sir.

Senator **Domenici**. Now, if Congress would like to have advice on that, and want to set it as a goal, and seek recommendations on how to get there, would it not be appropriate—that is if, if they do—would it not be appropriate in your opinion that we so state in legislation, and state it unequivocally?

And then ask somebody to do it for us, both as to recommending the timeframe, the costs, and how to do it?

Dr. **Wyngaarden**. I think it might, provided the resources were attitude resources.

Senator **Domenici**. I clearly understand that out in the research institutions of our country that we are in a situation where, whenever something new and different, an add-onto or completion of some endeavor is looked at by either you, that task force in the White House, scientists meeting under the aegis of the Academy of Science, or a committee, that we all are concerned that we do not want to disturb the resources of existing institutions, if they are doing a good job and their job is as high a priority as the one being envisioned or contemplated.

I sense that there is a natural, a naturalness, almost an inhibition on the part of existing institutions, when legislation such as this, with whatever problems there are with it, verbage-wise, or who should share the policy board and the like.

I sense that occasionally the directors of institutions such as yours look at it and can hardly remove themselves from the concern of, how is this going to affect what we are already doing.

And I might ask, if you were assured that it was not the intention of the legislation to in any way denigrate, detract from your ongoing activities, would you recommend that the United States of America have a policy of mapping the human genome as expeditiously as possible?

Dr. Wyngaarden. Yes, sir. Unequivocally, yes.

Senator Domenici. Would you recommend that we proceed with the sequencing of the human genome as rapidly as possible?

And let me add a subject too. Subject to recommendations from the most appropriate experts as to how rapidly we should move? And from what I have learned I will add the next caveat.

And that they be permitted to consider, after doing some of the sequencing, whether it is realistically good science to do it all. Would you recommend that kind of policy?

Dr. Wyngaarden. Yes. That is very consistent with the recommendations of the Directors Advisory Committee.

We took that point up very carefully and felt that it was urgent to proceed with the gene mapping, that the gene sequencing should be done, when methods permitted it to be done more economically, which is not that far off.

And that it would be very useful, perhaps, to do a model chromosome to see how much was learned.

Senator Domenici. Well, I want you to know that I am not familiar with the recommendations of the group you have just alluded to.

I have come up with this because you have been generous with your experts. In fact, Dr. Ruth behind you has educated me. She came to New Mexico and in one hour I learned everything that I am telling you here. Not very much, but nonetheless she is a pretty good teacher.

Now Dr. Wyngaarden, let me ask you this. It is true, is it not, that it is not the present charge to NIH, or to your knowledge any other department of the United States government, currently established department of the government, with a charge from the Congress, there is none around that has the responsibility of making the kind of policy that I just asked you two questions about, and that you answered in the affirmative? Is there?

Dr. Wyngaarden. Not that I know of.

Senator Domenici. You are not.

Dr. Wyngaarden. No, we are not.

Senator Domenici. DOE is not. Are they? Then I guess, and I regret that I was a lawyer because you will think that I am trying to practice law on you, but I am not.

I guess that I conclude, from the two questions that you have just answered, both of you, that if it was the will of the Congress that both of those national goals occur in the manner and as I described them, subject to, obviously, to the vagueries of who should do it and the like, I would assume that neither of you two would object to that occurring. Is that correct?

Dr. Wyngaarden. Yes.

Senator Domenici. How about you, Dr. Decker?

Dr. Decker. No.

Senator Domenici. Dr. Rona?

Dr. Rona. We have no reason to object.

Senator Domenici. And I assume Commerce, having talked with them, other than are there enough resources, you would probably as the lead agency worried about our competitiveness in the world, you would probably say yes to both questions, and say we ought to do it. Is that correct?

Mr. **Beringer**. Yes, we would.

Senator **Domenici**. And that we ought to have private sector involved wherever we can and as early as possible?

Mr. **Beringer**. Definitely.

Senator **Domenici**. I guess what disturbs me is if the case is as I just described it, what is wrong with this legislation that is before us?

And let me just be very specific about it. If we do not need a national policy board made up of the appropriate constituency to do the two things that we just described, and you remember that part of it is recommending so they do not necessarily have any money to spend yet.

If we do not need that, what do we need? And how do we do it? If Congress wants to do it, how do we do it? Just give the NIH more money under their existing program and give DOE some more money in one of its fields that it is currently involved in? Or how?

Either of you. Just do not speak together.

Dr. **Wyngaarden**. I think that is a very good way to do it. Yes, sir.

Senator **Domenici**. And would it get done?

Dr. **Wyngaarden**. Yes.

Senator **Domenici**. Without any changes in the law?

Dr. **Wyngaarden**. I think so.

Senator **Domenici**. Where would you get the direction to do the mapping? It is not around. You just told me there is no national policy and no statutory direction to do the mapping.

Dr. **Wyngaarden**. I think most of the things that we have accomplished in biomedical science are without a stated national policy.

They are done by providing resources to the scientists capable of doing the work. With guidance from the Congress as to priorities, and we respond to that.

Senator **Domenici**. Dr. Decker, do you agree with that?

Dr. **Decker**. Yes.

Senator **Domenici**. Well, I will tell you both, I love you both and I think you are great. But I just absolutely do not believe you.

I believe it would get done. But I am quite sure it would not get done in the most expeditious manner, because I do not think you would be charged with doing that.

I do not think you would send up any requests of a priority nature with reference to it, because you do not have enough money to do what you are doing. And if you tried to send up the request, they would be thrown in the waste basket by OMB.

And you would have to come up here and testify, in my humble opinion, on your own as witnesses declaring that you are totally removing yourself from your current roles. Because I just do not believe it would get done consistent with the way things are being done now in terms of research. I regret to say that.

Dr. **Wyngaarden**. Senator, my answer was predicated on an expansion of the national policy board along the lines of the earlier discussion, which I think would be able to set some of the goals that you are suggesting.

Senator **Domenici**. But Doctor, I hate to be argumentative, but I just do not know why they would set such goals, if we did not ask them to.

I mean, there are too many things on the platter out there. You all have an industry going in human genome activity. And it is superb. But it does not have any such mission. You have already said so.

You need bushels of money for what you are already doing. And that board kind of directs you and moves you. It seems to me it is an absolute natural, it is a national policy decision if we want to do it or not, and I frankly do not believe it will be done if we do not decide that we want to charge the national laboratories and the private sector to do it.

Dr. **Wyngaarden**. I may have misunderstood your question. I thought you said, if this was stated as a national policy. And it was followed by the provision of resources within the existing mechanism, would it get done.

And it was on that basis that I said yes, I thought it would.

Senator **Domenici**. I said, if we did not provide legislatively, and signed by our President, a national policy objective, that had the two goals that you have said you would support.

If we did not have that, I asked you if it would get done. And I thought you said yes, it would get done anyway. Is your answer that it probably would not get done?

Dr. **Wyngaarden**. No. I thought you said, if DOE and NIH were provided additional resources, could we accomplish this without additional legislation. It was that question that I said yes to.

Senator **Domenici**. Well, let me tell you there, I think the chances for getting it done are doubly remote, unless we affix to the money we gave you that you do it.

Dr. **Wyngaarden**. Fine.

Senator **Domenici**. Well, then we would have decided to do it, would tell you to do it.

Dr. **Wyngaarden**. Fine.

Senator **Domenici**. So we are right back where we are. If we are going to get it done expeditiously, and that is our goal, we have got to tell somebody that that is it and provide them with the resources to do it.

Dr. **Rona**. Mr. Chairman, if the intention is to establish a policy about the priority and the urgency of the research Senator Domenici was referring to, I do not think there is any disagreement among us that that is necessary and welcome.

It is perhaps just the mechanism which we may wish to examine. One possibility is to have a separate bill which in some way establishes a policy board and objectives. The other one is to simply indicate the will of Congress in the various appropriation and authorization bills.

That happens all the time. And I am pretty sure that my colleagues would welcome that.

Senator **Domenici**. I believe it is a very good observation, and I thank you for it. One last question, and then I would like to ask Commerce a question.

Let me ask you, Dr. Wyngaarden, you said to the distinguished Chairman that things were moving along quite well in the genome mapping and piecemeal selective sequencing, and the evolution of information gathering techniques.

And you said certain bills are providing money in the House, and you mentioned a couple of bills, an appropriations bill that has some money in it. I would like, again, since I have looked at those, and I think I know what they say.

But I wonder if we could clarify in this record, if those particular provisions of law, of legislation became law, and I am really hopeful they will, I am not opposed to them, is it not true that nonetheless we will still not have a policy that sets in motion the total mapping of the human genome and the sequencing as I described it before, sufficient to determine whether it is truly worthwhile to do it all or not? And a policy of timeliness and the like.

We still would not have that in place, if all that money was appropriated. Would we?

Dr. **Wyngaarden**. I think that is correct, Senator. There is not stated national policy worded in quite that manner.

There are, of course, many components of national policy that are set by Congressional initiative. For example, we have long been supported in our work in biotechnology and genetics and offer periodic reports to Congress on our work in those fields.

And I suppose in a way that is a national policy. But you are quite right. There has been no statement specifically on the human genome, as yet.

Senator **Domenici**. Dr. Decker, might I ask you, is one of the goals and objectives of the Department of Energy to significantly enhance the technology of genome mapping and ultimately sequencing?

And if the answer is yes, is not one of the collateral goals to dramatically reduce the cost of sequencing?

Dr. **Decker**. Yes, that certainly is a principal focus of the initiative that we have proposed.

Senator **Domenici**. Dr. Wyngaarden, is that a worthwhile approach for our country, knowing what you know about the problem?

Dr. **Wyngaarden**. Yes, indeed.

Senator **Domenici**. And you have no concern about the national labs being charged with trying to do that part of what we are discussing here?

Dr. **Wyngaarden**. Oh, no. None whatever.

Senator **Domenici**. My next question is for the Department of Commerce. Have you had an opportunity to review the most current contract between the University of California Laboratories at Berkley, Livermore and Los Alamos as they pertain to patent technology transfer?

Mr. **Beringer**. I would like to ask Mr. Latker to comment on that.

Mr. **Latker**. We are not involved in that negotiation, and we do not know of anecdotal tales regarding the negotiation.

Senator **Domenici**. Dr. Beringer, do you know about it? Does the Department of Commerce have a position on the proposed class waiver regulations that pertain to the subject matter about which I just asked you?

Mr. **Beringer**. Yes, we do, Senator Domenici. We have commented on those to the Office of Management and Budget.

Senator **Domenici**. You know, you almost respond as if you were in the CIA. [Laughter.]

You really know that what I want to know is what your comments were, do you not, now that you commented.

Mr. **Beringer**. I am afraid that is lawyer training.

Senator **Domenici**. Yes, indeed. You are well trained.

What is your conclusion after reviewing them with reference to their efficacy in expediting technology transfer?

Mr. **Beringer**. Let me just say, Senator, that we believe that class waivers establish the wrong type of presumption as far as the ownership of technology is concerned.

We believe that the presumption should be that the ownership would be in the contractor and then proceed from there. We think that this would be a better incentive, a better signal, for the private sector that, indeed, they would not have to go through a bureaucratic process in order to promote the technology that they, themselves, developed and would know best how to proceed to the marketplace.

So that is our general comment on class waivers. Maybe Mr. Latker would like to elaborate on that.

Mr. **Latker**. Just a general comment about our review of those regulations. I think we stated this in our objections to OMB. The class waiver does not treat as required by the President's 1983 memorandum on patent policy and the President's Executive Order 12591, that was issued April 10, I think, the same kind of treatment for performers other than small business and universities that is required by the memorandum and the executive order. It fails in that regard in a number of respects that are detailed in our objection to OMB.

Senator **Domenici**. Would you supply for the record further details on your objections for us, please, or would you want us to ask OMB? We will accommodate whichever way you want.

Mr. **Latker**. It is hard to just off the top of our head list all the objections.

Senator **Domenici**. I mean in writing later. I am not saying now. Can you supply them to us later in writing? That was my question.

Mr. **Beringer**. If you would ask the Office of Management and Budget, Senator, there is an internal administration document.

Senator **Domenici**. We will do that. Thank you.

I know enough about it to know that substantial portions of the laboratory's research will remain. Even if the waivers were carried out, substantial portions would remain subject to the very detailed waiver, and substantial portions are not even waiveable, even with the executive order and the regulations.

I might ask one last question. How long have those regulations been under consideration?

Mr. **Beringer**. I believe since March 23 of this year, Senator. If that is not correct, why, we will correct that in the record.

Senator **Domenici**. That is the last episode. That is the one that has to do with complying with the President's executive order that he spoke of in his State of the Union Address; is that right?

Mr. **Beringer**. Yes, sir.

Senator **Domenici**. Had the Department of Commerce and the DOE previously thereto had negotiations with reference to the waiver activities of the Department of Energy and its labs?

Mr. **Beringer**. We have had a number of conversations over the years, yes, sir.

Senator **Domenici**. Have you ever achieved a result that you could, as an agency, tell the Office of Management & Budget had achieved the maximum goals of then existing law? Forget about the executive order.

Mr. **Beringer**. I do not believe so, sir.

Senator **Ford**. Senator Evans?

Senator **Evans**. Let me return to some basics so that I understand a little more of what we are talking about.

Dr. Decker, in your paper on page 2, you say that a person's genome also determines whether one will develop one of the more than 3,000 known genetic diseases.

If you identify the elements of a person's genome and they contain one or several of the known genetic defects, is it accurate to say that a person will aquire that disease or is likely to?

Dr. **Decker**. Yes, but I think I had better defer to Dr. Wyngaarden, who is the expert on this subject.

Dr. **Wyngaarden**. Your question is insightful. There are many genetic predispositions that require some sort of environmental factor in addition.

Senator **Evans**. So the identification of a certain genetic defect in human genome would not necessarily ensure that the person would acquire that particular disease that flows from the defect?

Dr. **Wyngaarden**. No, sir. A very simple example: All of us would have scurvy genetically were it not for taking Vitamin C every day.

Senator **Evans**. When you talk about 3 billion nucleotides, more or less, are those all separate and unique, or is there a great deal of redundancy? Are we really talking about 3 billion separate pieces of information in a human genome?

Dr. **Wyngaarden**. There are approximately 3 billion nucleotides and 23 pairs of chromosomes. Each chromosome is a long strand of DNA, and the code is determined by the sequence of bases, and there are multiple possibilities. Basically there are four kinds of nucleatides, and the sequence of these determines the genetic codes. So it is a matter of determining the order in which these occur repetitively throughout the strands of DNA.

Senator **Evans**. When you say 3 billion in those strands of DNA, is each one identifiable as separate and distinct? Or are there redundancies where you have the same sequence?

In other words, are there 3 billion quite different and distinct elements?

Dr. **Wyngaarden**. There are 3 billion individual elements. Think of each one as a letter of the alphabet. There are 26 alphabet letters, and you can make millions of words out of those.

Here, you have four types, and the arrangement of those in different sequences determines which amino acid goes where and so on. You can have multiple arrangements of amino acids that then confer individuality on the proteums involved.

So it is made up of very simple elements, but there are 3 billion of those very simple elements to be determined.

Senator EVANS. But the 3 billion are 3 billion quite separate ones, each one distinguished from the other?

Dr WYNGAARDEN. Yes.

Senator EVANS. From the combined expertise here I have understood that with a certain amount of money, in at today's dollars, $3 to $5 billion over a ten-year period, that you could complete the mapping of genomes?

Dr. WYNGAARDEN. It is estimated that one could complete the mapping and the sequencing. It is not certain that every last component could be. There may be some refractory regions in which work needs to be done.

Senator EVANS. Essentially, we know how to do it?

Dr. WYNGAARDEN. Yes. The technology is available.

Senator EVANS. But it is a matter of just doing it?

Dr. WYNGAARDEN. Yes.

Senator EVANS. Once you have done that, just to look ahead for my own scientific information, if we had tomorrow that complete mapping done and stored, could we then presumably compare any human being against that inventory or map?

Dr. WYNGAARDEN. Yes, but there is likely to be a substantial amount of variation among human beings. Only identical twins would have precisely the same chromosomes. what we hope to establish is a general basic pattern upon which there are then variations, and these variations are what confer individuality among individuals.

Senator EVANS. If we had that mapping and had it computerized, even though it is a lot of information and perhaps pretty tedious even with today's high speed computers, is it conceivable at some time in the future you could feed in the uniqueness of a certain person's genome and then deduce that this person has these 19 genetic defects and susceptibility to this or that or several other diseases?

Dr. WYNGAARDEN. Yes.

Senator EVANS. How effective would that be in advancing both our knowledge and treatment of disease as we now know it?

Dr. WYNGAARDEN. Well, it is not possible to say precisely, but we would anticipate that this knowledge will provide new insights into the genetic contribution to a great many diseases, not only these well-marked hereditary diseases that we now recognize but such problems as familiar predispositions towards certain kinds of emotional problems, for example, in our genetic basis and manic depressive psychoses that have been identified only in broad terms. It might be possible to identify precisely what sort of genes control those reactions.

So one of the points is that this will enormously advance the understanding of living forms, not just man but all biological systems, and will give us, we trust, new insights into the way in which environmental factors, for example, radiation, might trigger certain changes in the genetic material that then predispose to certain cancers.

Senator EVANS. That was really my next question. If you compared people who had certain known environmental exposures against this map, you would be able to develop increasingly more and more knowledge about the potential environmental impact on health; not just radiation but a wide variety of other pollutants or naturally occurring elements?

Dr. **WYNGAARDEN**. Yes. This may lead to whole new strategies of prevention.

Dr. **DECKER**. Of course, that is one of the main interests of the Department of Energy in this project.

Senator **EVANS**. That is all very interesting. I guess I will ask Dr. Rona this question. I am sure you will not want to answer it.

This bill alone proposes three very big and interesting and quite distinct areas of focus: semiconductors, superconductivity, and the human genome. Each of those is interesting, different, all important in its own way. Each one carries with it a significant price tag in order to move ahead with research and development expeditiously.

Would you care to rank those in order of their importance? It seems to me that they all seem to come out about $4 or $5 billion each, plus or minus a billion or so.

Dr. **RONA**. Senator Evans, that seems to be a constant of the universe. You cannot do anything without spending $5 billion.

[Laughter.]

Senator **EVANS**. So tomorrow I will give you $5 billion, and you pick one of the three. Which one would you pick?

Dr. **RONA**. Well, these are at various stages of advancement.

Senator **EVANS**. I understand. It is a thoroughly unfair question.

Dr. **RONA**. Let me try to address them very briefly.

The semiconductor business has been with us now for the best part of 20 years, and the problem is how to organize our background or talent or motivation.

I do not think we have any big theoretical problems. There are enormous problems as to how to get our knowledge into practical implemental operations.

In the area of superconductors, this is a surprise to many of us, including the policymakers. We frankly do not know where it will lead. It is possible that the breakthrough is of the type described by those who are enthusiastic. It is also possible that we will be with it for ten years. We have an urgent interest to find out which is which. I think the bill will certainly help us to get in that direction.

The genome, as I pointed out a little bit earlier, is a problem which has extremely deep profound impact on our future. We just pointed to some of the possibilities which it raises, essentially examining a human being in great microscopic detail and finding out what happens to him or her and what is likely to happen.

Senator **EVANS**. I am more interested in what is likely to happen. I know what has happened.

Dr. **RONA**. Well, if you ask me to rank them, my priority, I would say the genome mapping is certainly number one. That is just a personal opinion.

Senator **EVANS**. A good candid assessment. I should have thrown in as a fourth one one that we are not talking about today but one which certainly is immediate and in front of us in terms of potential funding—the superconducting super collider.

Would you care to rank that on?

Dr. RONA. No.

Senator DOMENICI. Now, you really are meddling.

[Laughter.]

Senator EVANS. Well, as long as I am meddling I might as well do it well.

Senator FORD. It is my judgment we have given away enough of the knowledge on the superconductors and super colliders that somebody else could get it done for us.

Dr. RONA. That was your question, Senator?

Senator EVANS. I probably should withdraw the question, because it is an unfair thing to try to give priorities.

I think it is serious to this extent. We are talking about something extraordinarily interesting, and by luck of the draw or research science is coming together today on several very, very important potential breakthroughs. Each one of these will take a large amount of money which we probably do not have, at least not all at once.

So, ultimately, setting priorities is what the policymakers have to do. And I think to do it right we have to or should depend on the advice of scientists as to where we should and have to focus our efforts. If we cannot do everything at once, we have to put them in some order of priority.

Dr. RONA. Well, the genome and the super collider are projects of the type which the Federal Government certainly should take the initiative. It is not accessible to industry. The two others, industry can take an enormous amount of responsibility to further our interests because profits are to be made.

Senator EVANS. Thank you. I appreciate that.

Senator FORD. Thank you, gentlemen. We appreciate your coming today and your almost forthrightness.

[Laughter.]

Senator DOMENICI. I am going to ask the DOE in writing for two other summaries, but I will not ask the question. I will just propose it in writing and ask that they submit their answer.

Senator FORD. You gentlemen may be excused.

We have a real problem. We have another vote on the Senator floor. Senator Domenici and I both have appointments almost momentarily.

Senator Evans, what is your schedule the rest of the afternoon?

Senator EVANS. I said I could be here until about 3:45 p.m.

Senator FORD. I am in about the same position. I am trying to accommodate everybody. We have several people here from—I started to say out of state, but D.C. is not a state yet and probably will not be.

The second panel, we have Dr. Mendelsohn, Dr. Cantor, Dr. Miller and Dr. Postma. All are from other states, and then we have Dr. Gilbert from Cambridge, Massachusetts.

Is there anyone who cannot stay over until tomorrow? We may have to push this over and finish it up tomorrow. I do not know how to get through any other way. We are going to have to go vote. That is 15 minutes, and others have appointments.

Does anyone have any suggestions to help me out of this dilemma? You can file your statements for the record, and we will go over them. We already have those statements.

Why not try this. Let us let panel two come forward, then, Dr. Mendelsohn, Dr. Candor, Dr. Miller and Dr. Postma, and Dr. Gilbert and Dr. McKusick. Why do you all not come to the podium, and we will see if we can expedite it that way.

Then that will leave panel four, which will be three additional members.

Why not start, Dr. Gilbert, and we will just go right down the panel with your statements.

STATEMENT OF DR. WALTER GILBERT, H.H. TIMKEN PROFESSOR OF SCIENCE, DEPARTMENT OF CELLULAR AND DEVELOPMENTAL BIOLOGY, HARVARD UNIVERSITY

Dr. **Gilbert**. I submitted a statement to you.

Senator **Ford**. That statement will be included in the record.

Dr. **Gilbert**. I think my basic comments on this project are that the project meets very clear goals, and I think it would be advantageous to have those goals set forth in legislation.

The goals of the project are the ones mentioned, both the mapping and the sequencing of the human genome, and the national project extending across one set of goals I think is very advantageous.

I think the project needs to have clear delegation of responsibility, some organization that is going to actually carry out those goals. I think that is the problem for the legislation, that it needs to specify either an agency or a national board that clearly has responsibility to carry out both the mapping and the sequencing.

I do view the project as having both a research component and a production component, but the basic effort, most of the money and most of the effort, will actually be spent on both producing a map of the human genome and producing a sequence of the human genome. Neither of those are research function.

Those need to be identified early. Those are the place that the work is going to be done, and those are either going to be done, I think, in structures like the National Laboratories or in structures in private industry.

I think one of the problems that the NIH approach to the project poses is that the way the NIH does research for the most part is very appropriate for research done by scientists, basic research in which you wish to stimulate as broadly as possible the individual initiative.

It is quite inappropriate for extremely applied research and for production, which is what this is, because the real effort here is to produce a tool to work out all the information in the human body, and that is what I mean by production, and put it in a structure, a data base, so that it can then become a research tool.

[The prepared statement of Dr. Gilbert follows:]

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H. H. Timken
Professor of Science

September 17, 1987

Testimony of Professor Walter Gilbert, on Title II of S.1480: Mapping the Human Genome.

In my view the Human Genome Initiative is a worthwhile project which will have far-reaching consequences in stimulating the growth of medical knowledge. However, the effort to understand the human genome has four components, not all of which are addressed by this legislation. The first element is the construction of a DNA map of the human genome, consisting of an ordered collection of DNA fragments that faithfully reproduces the DNA of a human being: The second component is a genetic map, a DNA polymorphism map, that will be used to find genes through population studies and to identify candidate positions of genes on the DNA fragment map. The third element of the human genome project is the sequencing of all, or a large part, of the human genome. It is this sequencing of whole chromosomes that will provide the catalogue of putative genes, the list of the structures of the hundred thousand genes, which make up the genetic inheritance of a human being. The fourth component is the analysis and distribution of the information contained in the sequence. All four components are necessary to achieve the goal of the Human Genome Initiative: to create an information resource that can display the complete structures of all the human genes.

Today, work on the polymorphism map is preceding apace through private initiative. However, that map will need to be extended and refined in conjunction with the DNA fragment map. Although the ordered DNA fragments themselves will be of value to the research and pharmaceutical community, the DNA fragment map is only an intermediate step in the construction of the ultimate map, the DNA sequence. 90% of the total effort in the human genome project will be in the working out of the DNA sequence. For that reason, I recommend that the goals of the project be stated explicitly as mapping and sequencing the human genome, to the end of developing essentially a complete sequence so that the structures of all the human genes can be known.

The projects of mapping, sequencing, and data analysis each consist of two parts. The first is the development of techniques: the improvement of the methods by which we map DNA, sequence DNA, and analyze the information content of those sequences. However, at the appropriate time each of these projects turns into a production effort. It is not sufficient simply to develop techniques; it is essential that the directors of the project must realize that the map must be produced and maintained, the sequence must be produced, and the database established and then distributed in a useful fashion. Title II of S.1480 describes much of the process as only involving the improving of methods and techniques and does not recognize the direct production part of the problem. In my view, the techniques are largely available today and need only be applied and focused in a production mode to create first the ordered fragment map and then, a few years from now, to begin the actual sequencing. This production problem could well be done by a collaboration between the National Laboratories and industrial companies. S.1480 should be modified so as to delegate clearly the responsibility to produce the map and the sequence.

The tool being created by the human genome initiative is the information, in the form of a database, to which one will be able to turn for primary sequence information as well as many layers of analysis. This information will stimulate, inform, and guide the research of the next century: the studies of human genes and their interactions. The medical profession will turn to this database as it attempts to identify all the human gene products that influence the structure and the growth of the body and the susceptibility of the organism to failure. The pharmaceutical industry will turn to this database as it seeks to identify new pharmaceuticals among the biologically active gene products.

The project should be seated in a structure that can take clearly identified responsibility. For that reason, I think it is quite appropriate to run such a project through the Department of Energy and have the policy board chaired by the agency which will take the major, separate responsibility. The consortium that is actually to run the project be should be housed in the Department of Energy. The consortium and the technical operation board are line functions and should have clear operational responsibilty.

The listing of goals in Section 202 (d)(1) should include "to work out the sequence of the human genome, consisting of the order of bases along each of the chromosomes." Section 203, objectives, only describes research initiatives; it should also spell out that the Secretary of Energy should initiate a cooperative program for the production of the mapping and sequencing data.

Amendment Number 483, subsection (d)(i), intellectual property rights, is too restrictive. This bill as amended would contain a statement that "the intellectual property rights in mapping the human genome and the devices developed under the initiative be controlled in such a matter that promotes the use of such technology and devices exclusively by United States industries". I regard this as counterproductive. Americans benefit when a medical advance is made anywhere in the world. Increased knowledge of the human genome will stimulate world science and medicine, not just that in the United States. The problem is created by the word "exclusively"; I recommend that that word be deleted. It is appropriate to encourage American companies to exploit the technological developments and to use the information created by the initiative, but the information in the database must be available for world medical research, and American companies which function abroad must be able to use the information without having to worry about disclosure. American industry and American science will benefit substantially through the initiative. The country that sequences the human genome will assume a commanding position in biological and medical research in the next century, even though its scientists will not make every last discovery that flows from that information.

Senator FORD. Dr. Postma.

STATEMENT OF DR. PATRICIA D. POSTMA, ASSOCIATE DIRECTOR, MBA CENTER OF EXCELLENCE FOR NEW VENTURE ANALYSIS, UNIVERSITY OF TENNESSEE

Dr. POSTMA. I appreciate the opportunity to speak with you today, and I think I have a different perspective in addressing Title IV than any of the other speakers you have had today.

I am delighted to do it because I think Title IV is unusually well timed, and if it is carefully done it could make a valuable contribution to technology transfer and national competitiveness.

By way of introduction, let me say that I am an economist. I am presently the Associate Director for the Center of New Venture Analysis at the University of Tennessee. I have been involved with technology transfer and economic development in a good many ways. I have been involved at the Oak Ridge National Laboratory in a good many ways. I have been a consultant and investor to small companies, several of those who are spinoffs of Oak Ridge National Laboratory.

So I have a daily involvement in this area and a very active interest in seeing it promoted.

We have made rapid strides in this area compared to five or six years ago, and that is because of a series of technology transfer acts and also because of some aggressive moves in that direction by Oak Ridge National Laboratory, but in some part it is due to a program rather like the one that is proposed by Title IV. I want to tell you a little bit about that.

In every case, commercial market uses for which technologies are spun off from national laboratories or universities will be different or in almost every case they will be different from the purpose of the development under the DOE mission. Along with a shift in use in the market comes a shift in technology requirements to suit commercial markets in uses that technology will need to have particular characteristics to make them attractive to exploit.

Furthermore, a lot of the technologies that come out of national laboratories will be far ahead of their markets. Advance materials are clearly recognized as having substantial impact on the way we do everything from cutting tools to automobile engines, but the problem is that is maybe five or ten years in the future and how to make economically attractive uses of those now.

Advance materials is a very large set of technologies, but I think that principle of the gap between the laboratory and the commercial use applies to many of the small technologies that would like to be transferred out of the laboratories as well.

In many cases this path from the laboratory model to the commercial use is the real barrier to technology transfer, and I see that within the national laboratories before technologies are licensed, before one even knows which potential customers might be interested in licensing, some business functions have to occur; that is, some market analysis and market research has to occur internal to the national laboratories.

For the most part, they are not equipped to do that, nor is it clear that we ought to convert researchers to do that function.

Concurrent with its recent buildup in technology transfer activities at Oak Ridge National Laboratory, the University of Tennessee MBA program, which has some special funding from the state, has established this Center of Venture Analysis. In the past 18 months, we have had eight MBA students who are working in the technology transfer activities at the national laboratory. They are working strictly in this area of market analysis to reduce that barrier to commercial application, and I would like to quickly cite three examples of the work those students have been able to do in conjunction with the laboratory.

Two of the students developed a technical data book to inform potential users about the characteristics of nickel aluminide, which is a high temperature material developed in the laboratory.

After they did their homework, the students were able to talk with a researcher and prompt him to specify and describe some characteristics of the material that he had not needed to address in the DOE research but which would make it attractive to commercial users.

In addition, they compiled a data book in a very user friendly market oriented format, and at least partly because of that work the technology was licensed for use in heating elements of household appliances a couple of weeks ago.

In another case, a student researched and identified 82 U.S. companies with the interest in advance materials, designed and administered a marketing survey which went out to those companies and had an extraordinary 72 percent response rate. The researchers and the technology transfer people were very impressed with the results of the market study, and the result of that was the formation of what we call CAMDEC, the Ceramics Advance Manufacturing Development and Engineering Center.

ORNL is now formally seeking corporate members to join CAMDEC, and their mission is to develop manufacturing processes for advance materials as opposed to basic research.

In the last example, I would like to cite, and I did cite some more of these in my additional material for the record, students who have been working in this program of technology transfer believe that they can see ways in which the whole process within the laboratory went on.

On their own initiative, they suggested that they do a review of the technology transfer process within the laboratory. They convinced their sponsors to let them do that, and they are currently conducting that evaluation and will write a formal report suggesting some ways to make the technology transfer process more efficient.

Our course is only two years old, but we have had some good results, both for the business school and for the laboratory at this point. It is the combination of the business school and the laboratory like the one that Title IV suggests. It has attracted some very top notch students to our program, and many of them are working at the laboratory.

I think we are far enough down the road of intentional technology transfer to recognize that it is easier said than done, and we do still need a variety of procedures to remove some of the barriers to it.

There is, as with other parts of this bill, a caveat and an opportunity in Title IV. The caveat lies in the orientation of graduate business school pedagogy as it currently exists. Only in the 1980s have we rediscovered the contribution of entrepreneurial factors to our economy.

The graduate business curriculum is firmly based on our traditional assumptions, and courses are taught from the perspective of established resource rich corporate environments that operate in efficient capital markets and efficient information markets.

From experience with both new ventures and with business school curricula, I can tell you that while a lot of the topics we need to teach entrepreneurs are the same generic tops, the method in which they have to be approached is very different.

We are only just now beginning to develop that entrepreneurial pedagogy. There is a network of dedicated faculty around the country that talks with one another and exchanges course material, and we have often used successful entrepreneurs in course development.

We get our readings wherever we can find them. I think there are fewer textbooks in this field than I can count on on hand. There is only one textbook I am aware of that addresses it at the graduate level and only one textbook that addresses a specialized aspect of entrepreneuring.

Empirical research, which will provide the long-term basis for this course material and for a theoretical framework and effective training, is at a similarly early stage. We must do more in that regard as well.

Now, I think all of us agree that these high growth companies are a primary source of jobs and of international competitiveness in the forseeable future, and I think they deserve the same theoretical development, the same course work, the same material support as the mature corporate sector of the economy. This is an opportunity that I think Title IV can address and perhaps it did not intend to address or realize it had the opportunity to address.

I think that while Title IV should concentrate itself on a core of business specialists who can handle the particular problems of technolgy innovation, it will have a significant acceleration effect on the whole area of entrepreneurship training, no matter what the entrepreneurial focus is.

In other words, you can play a strategic role in something that is important to the entire economic growth but especially important to the technical transfer, and it seems to me that the timing right now, coming where it does in our experience with technology transfer and our experience with beginnings of developing entrepreneurship training, is optimal. The technical springboard of the national laboratories is a marvelous asset to this development.

I do have some suggestions for modifications of Title IV. I think that the curriculum suggested is a desirable one and a reasonable one, but I do not think you ought to dictate it in each and every case. I think there ought to be a good deal of flexibility as to how the objectives of entrepreneurship training and joint venturing with national laboratories are undertaken.

The same comments apply to the work study arrangement. If the statement that the student will work on a specific project means that he or she would be involved with the single same project throughout his educational period, I think that would be seriously counterproductive.

I am also puzzled by the absence of specifications in the criteria with respect to business schools. What Title IV proposes to do is very challenging, and I have addressed that business school issue more in my comments, but I think it requires a committed school, and I would like to see some attention paid to that in terms of the specifications.

I would like Title IV to encourage the business schools' role with the laboratories as I think it does implicitly while the student is in training; that is, one thrust of Title IV is to produce entrepreneurs who will then after their education go out and begin companies that use laboratory technology.

As I have pointed out, however, some very real and substantial benefits can occur during the education process to the laboratories, and I would like to see that encompassed.

Finally, I would like you to address head on the opportunity that Title IV has in terms of being a focal point for the systematizing and congealing, if you will, of entrepreneurial education that is just at its early stages.

I am very strongly in favor of it. I think, carefully done, it could make a wonderful contribution, and you have my assistance in any way you can make use of it.

[The prepared statement of Dr. Postma follows:]

Testimony
of
Patricia D. Postma

Associate Director, MBA Center of Excellence for New Venture Analysis
University of Tennessee

Before the
Subcommittee on Energy Research and Development
Committee on Energy and Natural Resources
United States Senate

2:00 p. m., September 17, 1987
Room SD-366, Dirksen Senate Office Building
Washington D. C.

S.1480
Department of Energy National Laboratory
Cooperative Research Initiative Act

Chairman Ford and members of the committee I want to thank you for the opportunity to talk to you today. I believe I have a different perspective from my associates on the panel today in addressing Title IV. Aside from the honor of addressing you I am delighted to be here because I believe Title IV is unusually well-timed and that, carefully done, it will, in fact, make the valuable contribution to economic development and competitiveness that you want to result from S. 1480.

By way of introduction I am Dr. Pat Postma. My interest in S. 1480 comes from a variety of involvements with technology transfer, economic development, and business school curricula. I am Associate Director of the MBA Center for New Venture Analysis at the University of Tennessee and teach a graduate course in Venture Finance. I have been a consultant to or an investor in a number of early stage technical companies, many of them spinoffs from Oak Ridge National Laboratory (ORNL).

Over the years I have had various associations with ORNL. I had long held the conviction that the technical developments at ORNL were overwhelming while the results in terms of national and local economic development were underwhelming. That is now changing rapidly as a result of the Stevenson-Wydler Act, the Bayh-Dole Act and the Technology Transfer Act of 1986 followed by aggressive implementation of those measures by ORNL and, in part, because of a program like the one proposed by Title IV. The technology transfer acts removed some of the legislative and attitudinal barriers to technology transfer from the national laboratories. Title IV can remove a significant practical barrier.

I said that Title IV was timely and that it could work. Let me address those in reverse order.

The Title IV Concept Can Work: "Demonstration Project" at the Oak Ridge National Laboratory and the University of Tennessee

In almost every case, the commercial market uses for which technologies are spun off from the National Laboratories will be quite different from the purpose for which it was developed under the DOE mission. Along with that shift in market and customers come different technology requirements. The technology will need to have certain characteristics or provide certain benefits in order to be commercially attractive to exploit.

Furthermore, technologies developed within national laboratories will generally be far ahead of their markets. For example, advanced materials are clearly recognized as having the potential to revolutionize the way we make everything from cutting tools to automobile engines. Nevertheless we don't know where the most economically feasible early markets are *now.* That fact is generally acknowledged about advanced materials but the same problem exists with respect to almost every "small" new technology, too.

That is, in the stage at which they have satisfied the DOE and National Laboratory mission, most inventions and technological innovations are economically neutral. In many cases the path from laboratory model to financially successful commercial product is so obscure as to be the real barrier to technology transfer. *Thus, within the National Laboratories, before licensing, often in order to even identify potential markets and licensees, one important business function -- market identification -- must occur.*

Concurrently with the buildup of technology transfer activity at ORNL, the University of Tennessee MBA program, with special funding from Tennessee's Centers of Excellence program, has established the Center for New Venture Analysis with a curriculum very similar to that proposed in Title IV. In the past 18 months the University has had 8 venture-oriented MBA student interns at work in the technology transfer activities at Oak Ridge National Laboratory in an effort to reduce the commercial applications barrier. These students have worked on a number of different projects. I want to quickly cite three.

1. Two students developed a technical data book to inform potential users about the characteristics of Nickle Aluminide, a high temperature material developed at ORNL. From their background research the students were able to prompt the scientist to specify characteristics that he had not originally addressed for DOE purposes. They also designed an accessible, customer- friendly format for presenting the information about Nickle Aluminide. At least partly because of that work, the alloy was licensed for use in heating elements of household appliances a few weeks ago.

2. One student identified 82 U. S. companies with an interest in advanced materials, then designed and administered a marketing survey which had an extraordinary 72% response rate. The scientists with whom she worked and the technology transfer people thought the survey and the analysis of it were outstanding. The result was the formation of the Ceramics Advanced Manufacturing Development and Engineering Center. ORNL is now formally seeking corporate members to fund further research on the processes of manufacturing advanced materials. This consortium, I believe, has been a subject of discussion recently in the House Committee on Conservation.

3. After working with the technology transfer activities and seeing what he believed were inefficiencies one student proposed that a student team review the technology transfer process. The team is currently evaluating each step in ORNL's

process from the means of awarding inventors to communicating the technologies to outside industry. Their report will make concrete suggestions for changes and is directed at making the technology transfer process more efficient.

I should point out that although our program is only 2 years old several of our outstanding students came to the University of Tennessee because of the *combination* of a course in entrepreneurial studies and the technical community centered around Oak Ridge National Laboratory. I believe the activities I have described, and the students involved in them, exemplify the intent of Title IV, though the benefits are occurring at a much earlier stage than it suggests.

This is a very propitious time to mount a program like Title IV and Title IV can play a very strategic role in entrepreneurship education.

Title IV is timely because we are far enough down the path of intentional technology transfer efforts to recognize that it is easier said than done. It needs a variety of new efforts in procedures to removing the commercial applications barriers I mentioned. Thus, this is a good strategic point to design effective additional tactics.

Title IV is also timely because of its focus on entrepreneurial *education*. Title IV implies a rigorous and systematic approach via a Master's level program. This is as it should be, I believe, but therein lies both a caveat and an opportunity.

The caveat lies in the orientation of graduate business pedagogy. It has only been in the 1980's that we have *rediscovered* the contribution of entrepreneurial ventures to economic growth. The graduate business curriculum is firmly based on our traditional assumptions and courses are taught from the perspective of established, resource-rich corporate environments operating in efficient information and capital markets. From experience with both new ventures and graduate business programs I can tell you that the body of material that makes up entrepreneurship education, though it will deal with many of the same topics, must treat those topics very differently.

We are just beginning to develop a distinctive pedagogy of entrepreneurial business. There is a network of dedicated faculty around the country that talks about what is effective, exchanges course material and, often, involves successful entrepreneurs in the development process. We get our readings wherever we can find them. I can count the number of textbooks on one hand and I am aware of only one, just published, that deals in depth with a specialized aspect of venture management and only one intended for graduate level use. Empirical research, which must provide the long-term framework for teaching entrepreneurial development successfully is at a similar early stage.

If it is true, as we now believe, that young, high growth companies are the primary source of job growth in this country and they are an extremely important part of the commercialization of innovation and of international competitiveness, then they deserve the same serious research, the same theoretical development, the same specialized textbooks as does the mature corporate sector of our economy. Herein lies the opportunity.

Although the federal commitment through Title IV should concentrate on training a core of business specialists versed in technology innovation and its specialized requirements the recognition of entrepreneurial business education that would come with the proposed Institutes and their assumption of a focal role at this early stage of development would have a significant acceleration effect on what has just begun.

While I expect that it was probably not the intention of Title IV to play a strategic role in the development of entrepreneurship education nor to legitimize the entrepreneurial sector of the economy, the timing and the technical springboard of the national laboratories makes that an obvious role. I encourage you to meet that hidden opportunity head on because, as the series of technology transfer acts recognize, innovations are, of themselves, economically neutral. Effective entrepreneurship is an extremely critical piece in our future competitiveness and we don't know everything we need to know about it.

Important modifications of Title IV

I have three broad suggestions for modification of Title IV.

1. The curriculum proposed is desirable and reasonable but I believe the legislation must allow for some flexibility. The intent can be accomplished in more than one way. The same comments apply to the work-study arrangement; in

particular, if the statement that the student will "work on a specific project" means he or she should be involved with the same single project throughout the study period I believe that would be seriously counter-productive to entrepreneurship training.

Along these lines of specifications I am puzzled by the absence, in the criteria suggested for selection, of any reference to the quality or commitment of the candidate university's business program. What Title IV proposes to do is challenging for business schools as I describe in my lengthier written testimony, and that should be a substantial consideration.

2. Title IV should encourage the business school's potential role in the entrepreneurial activity that must be carried on within the laboratories before a technology can be transferred. By that I mean the product and market analysis that helps the laboratories identify and communicate with potential users or licensees.

3. Title IV should encourage the Institutes to play an explicit role in developing the educational field of entrepreneurial venture development and management.

Suggestions notwithstanding, I hope I have made it clear that I strongly support the intent of Title IV. I extend my support and assistance to the Committee in any way you can use it.

Supplementary Material for the Record
Relating to the Testimony
of
Patricia D. Postma
Associate Director, MBA Center of Excellence for New Venture Analysis
University of Tennessee

Before the
Subcommittee on Energy Research and Development
Committee on Energy and Natural Resources
United States Senate

2:00 p. m., September 17, 1987
Room SD-366, Dirksen Senate Office Building
Washington D. C.

S.1480
Department of Energy National Laboratory
Cooperative Research Initiative Act

The Title IV Concept Can Work: "Demonstration Project" at the Oak Ridge National Laboratory and the University of Tennessee

In my testimony to the Committee I suggested that the internship program between the University of Tennessee's MBA Center of Excellence for New Venture Analysis and Oak Ridge National Laboratory (ORNL) serves as an example of the positive benefits of Title IV of S. 1480. The Committee may find it helpful to know more details of that program and the Laboratory relationship and I have provided it here.

The MBA Center of Excellence for New Venture Analysis

The Center for New Venture Analysis was established in the Spring of 1986. It is comprised of four faculty members including Director Dr. Alex Miller and Associate Director Dr. Pat Postma. The Center is a part of the MBA program and has developed three graduate level courses -- Venture Finance, Market Opportunity Analysis, and Venture Management -- which constitute a concentration in Venture Analysis.

"Center of Excellence" is a designation by the Tennessee Higher Education Commission. It is intended to recognize and give special financial assistance to selected programs in the State's institutions of higher education that have or can achieve national stature. Thus the Center for New Venture Analysis has as a central objective a quality of entrepreneurial education and research that will rank it among the leaders in this field.

The Center distinguishes between "small business" and entrepreneurial ventures and focuses its efforts on entrepreneurial ventures. Small businesses are those that are likely to remain small in terms of total revenue; whose ownership will most likely remain closely held among family or a few partners; which serve local markets as opposed to national or international markets. Generally speaking these business are not based on innovation.

Entrepreneurial ventures are based on an innovative technology or practice of some sort; they have the potential and the objective of fast growth and high revenue; they serve national and international markets. These ventures may be independent startups and early-stage companies or they may be "intrapreneurial" -- distinct, innovation-based businesses within larger companies. In addition to a focus on "entrepreneurial" as opposed to "small" business, the Center for New Venture Analysis has a special commitment to technology-based ventures because of the rich network of cooperative arrangements between The University of Tennessee and Oak Ridge National Laboratory research communities.

Student Work Relationships at Oak Ridge National Laboratory

Technology transfer at ORNL takes several forms. Generally these include collaborative agreements for industry research at user facilities on the ORNL site or licensing technologies for use by flourishing existing companies elsewhere in the country or they may license to startup companies -- usually in the Oak Ridge/ Knoxville area. In the past 2 years ORNL has licensed 15 technologies, 7 in the local area.

Over the past 18 months 8 MBA students have worked as interns on technology transfer activities with Oak Ridge National Laboratory. Their tasks have been in various aspects of marketing and they have served the needs of both internal user facilities and external licensing. This marketing relationship developed as a result of the strong marketing program at the University's business school and the immediate needs of the technology transfer program at ORNL.

The projects have included:

1. Earlier DOE sponsored research on energy conservation resulted in a innovative bioprocessing technique to produce ethanol. University MBA students worked with researchers to learn the characteristics of this sol-gel technology and identified hazardous waste treatment as a promising area of commercial application. ORNL has reapplied for related patents and has had licensing discussions with one private company.

2. ORNL is internationally recognized as a leader in advanced materials technology; transferring these technologies is and will continue to be one of the success stories of the DOE technology transfer program. One student identified 82 U. S. companies with an interest in advanced materials, then designed and administered a marketing survey which had an extraordinary 72% response rate. The scientists with whom she worked and the technology transfer people thought the survey and the analysis of it were outstanding. The result was the formation of the Ceramics Advanced Manufacturing Development and Engineering Center. ORNL is now formally seeking corporate members to fund further research on manufacturing processes for advanced materials.

3. The same student carried out a marketing plan to identify and attract users of the conservation program's Roof Research User Facility which provides facilities and equipment allowing industrial members to test roof sections and analyze data.

4. Two students developed a technical data book to inform potential users about the characteristics of Nickle Aluminide, a high temperature material developed at ORNL. From their background research the students were able to prompt the

researcher to specify characteristics that he had not originally addressed for DOE purposes. They also designed an accessible, customer- friendly format for presenting the information about Nickle Aluminide. At least partly because of that work, the alloy was licensed for use in heating elements of household appliances a few weeks ago.

5. One student researched potential uses of a particular medical isotope by interviewing clinical researchers and drug companies. The result was a workshop at which information on the research and on licensing procedures was transmitted to industry participants. That student has graduated and is now a full-time employee of ORNL working with the technology transfer activities.

6. One student assessed potential uses of Hermes 2, ORNL's autonomous robot. He concluded that the capabilities were too costly for the commercial market at present except in the area of high performance security operations.

7. One student is working with an ORNL-University consortium (Tennessee Consortium for Research and Development) which is doing second-generation improvements to MIT software for finite element analysis. The improvements are intended to make the software more commercially attractive. The student's task is to construct a "profile" of support service that would be needed for the software and thus a profile for an independent company that could service the software once it is commercial use.

8. After working with the technology transfer activities and seeing what he believed were inefficiencies, one student proposed that a student team review the technology transfer process. The team is currently evaluating each step in ORNL's process from the means of awarding inventors to communicating the technologies to outside industry. Their report will make concrete suggestions for changes and is directed at making the technology transfer process more efficient.

In addition to these direct associations with Oak Ridge National Laboratory, students in the Venture Analysis are involved with entrepreneurial ventures through field projects in courses. For example, Market Opportunity Analysis students worked with American Matrix, Inc. (a company which has developed proprietary processes for manufacturing silicon whiskers and platelets for reinforcing ceramic materials) to identify potential markets for their innovation. Students in Venture Finance worked with Computer Technology and Imaging, Inc. (A company using proprietary Positron Emissions Tomagraphy technology for diagnostic imaging). Students used a variety of methods to determine a market value for the company for expansion financing.

Both of these technical companies are second generation spinoffs of ORNL technologies rather than newly spawned technology transfers. Nevertheless their innovative products are at a stage of development that poises them for the kind of global competitiveness that the technology transfer acts are aimed at enhancing.

In all of the examples I have presented, students rendered to the Laboratory and the technical companies involved services of substantial creative and market value. Title IV is aimed at producing future national benefits in the form of trained entrepreneurs familiar with the technologies and technology transfer procedures of the national laboratories. ***I want to emphasize, however, that Title IV can also produce immediate benefits through student involvement during the training period.***

Two MBA students currently involved in internships at ORNL may exemplify the attraction of a Title IV Institute. One of them was an engineer working in the energy field in New York state. He became a partner in a sporting goods store in his spare time. He decided he wanted to learn more about business and came to East Tennessee last year because of all the energy-related activities and because the University has an entrepreneurship major in its MBA program.

This year a Canadian student with a degree in Metallurgy and a score of 770 out of 800 on his graduate admissions test came because of the combination of the University's program and the technical community in East Tennessee. He is interning with the Laboratory's Metals and Ceramics division and he intends to be part of a technology venture when he graduates.

Title IV recognizes the unique opportunity of combining entrepreneurial training with innovative technologies at their source. These students did, in fact, join the program because of that *combination.* One had established a professional niche; the other came directly after his undergraduate work. Both found something here that they did not find elsewhere. I believe Title IV Institutes will attract outstanding students who can make substantial contributions to economic growth and international competitiveness.

Other programs at the University of Tennessee which contribute to achieving the objectives of Title IV and technology transfer.

The Science Alliance

The Science Alliance is the largest of Tennessee's Centers of Excellence. It direccts joint research and education programs in which faculty, students and staff from the science departments at the University work with ORNL. It is expanding the research collaborations that have developed over the years and will promote technology transfer to industry. The Director is Dr. Paul Huray. During 1986-87 Dr. Huray served as Senior Policy Analyst for the Office of Science and Technology.

The Science Alliance provides an environment for research and training that neither institution could achieve singly. The Science Alliance has established the Joint Institute for Heavy Ion Research and the Institute for Resonance Ionization Spectroscopy. Based on the strengths of the Science Alliance community 4 other institutes are in various stages of proposal or design. These include the Institute for Applied Microbiology, the Center for Environmental Biotechnology, Center for Biomaterials Research and the Center for Biomedical Imaging.

One of the most significant contributions of the Science Alliance is the Distinguished Scientist Program. In Cooperation with Martin Marietta Energy Systems, Contractor for Oak Ridge National Laboratory, the University appoints internationally renowned scientists to joint positions at ORNL. Funds for ORNL's share are provided by the Department of Energy. The Distinguished Scientist may draw upon the resources and facilities of either institution to support research and teaching and external grants may be funded through either institution. This successful program has recruited 12 Distinguished Scientists to date and full implementation of 30 positions will take place over the next 4 years.

The University Venture Capital Center

The University Venture Capital Center (UVCC) was created to aid in overall economic development in the State by increasing venture capital activities. The UVCC responds to requests from inside or outside the University concerning venture capital availability and will arrange meetings between entrepreneurs and venture capital firms when that is appropriate. Occasionally, especially when University research is involved, UVCC may provide some exploratory market research. Student interns from MBA Center for New Venture Analysis work with UVCC to do market research.

UVCC formed an initial working relationship with Venture First Associates of Winston-Salem, North Carolina. Venture First Associates provides an initial evaluation of intellectual properties that emanate from the University's research activities. Since that relationship was formed 2 years ago Venture First Associates has led investment syndicates involving several other venture capital firms to invest more than $30 million in Tennessee ventures, primarily in the Oak Ridge/Knoxville area.

This is a very propitious time to establish the Institutes of Title IV and Title IV can play a very strategic role in entrepreneurship education.

Title IV offers a fortuitous opportunity for playing a key role in our ability to successfully foster entrepreneurial ventures of all kinds because of its timing. Some background that illuminates the juncture at which we find ourselves may be helpful to the Committee.

Our current expectation that entrepreneurial ventures can foster economic growth and international competitiveness, or are specially suited to introducing innovation, is a rather new expectation. It can be dated, I believe, to a study Dr. David Birch of M. I. T. conducted for the Department of Commerce in 1982. Using Dun and Bradstreet data Dr. Birch found that small firms, new ones in particular, generated most of the new jobs in the United States every year.

These facts are commonplace now, but the speed at which they have become commonplace is, in itself, testimony to the startling nature of Dr. Birch's findings. The United States had been accustomed to thinking of itself as thriving on its large corporations. These were the apparent source of economic growth and innovation as evidenced by large R & D budgets.

This growth myopia no doubt has complex causes but can perhaps be summed up by saying that the entrepreneurial economy was officially invisible. Although there are federal data collected which could shed light on the growth patterns of new companies it has not been construed in this way and has not been available to researchers. (By special agreement with the State of Tennessee researchers at the University of Tennessee are undertaking a unique study of entries and exits of businesses in Tennessee using employment security data.) Similarly there had been little or no field work.

It is inherently difficult to collect data on many small firms, but underlying the lack of effort is the fact that in the last few decades the entrepreneurial resource had disappeared from economic theory too. Adam Smith clearly identified an entrepreneurial role in the 18th Century; Alfred Marshall recognized it 100 years later and Joseph Schumpeter, a leading economist writing in 1939 understood that the introduction of innovation is always associated with a particular individual and he saw this process as "the essential fact about capitalism." As microeconomics has focused on abstract models of the firm and macroeconomics has focused on statistical aggregates and elaborate econometric models individuals and innovations have disappeared from theory and from the educational process. A recent article from *The Wall Street Journal*, included as Exhibit 1, addresses this absence in current economic education.

Having rediscovered the importance of the entrepreneurial sector to economic growth and innovation we were unprepared to deal with it educationally. The graduate business curriculum is firmly based on our traditional assumptions and courses are taught from the perspective of established, resource-rich corporate environments operating in efficient information and capital markets. The body of material that makes up entrepreneurship education, though it will deal with many of the same topics, must treat those topics very differently.

We are just beginning to develop a distinctive pedagogy of entrepreneurial business. Where courses have recently appeared they have generally appeared because of a "champion" -- a faculty member who was himself involved with ventures and convinced of their contribution, and who, in the light of recent developments, believed that a formal course had a place in the business school.

The recently added courses in entrepreneurship are encouraging but they are by no means integrated into the business school curriculum. Professors are notorious for defending their disciplinary turf. There are never enough resources and new courses threaten budgets as well as well as theories.

More legitimately the dearth of academic rigor based on research and systematic theoretical development poses a problem for business schools. We get our readings wherever we can find them. I can count the number of textbooks on one hand and I am aware of only one, just published, that deals in depth with a specialized aspect of venture management and only one intended for graduate level use. Empirical research, which must provide the long-term framework for teaching entrepreneurial development successfully is at a similar early stage.

There is a network of dedicated faculty around the country that talks about what is effective, exchanges course material and, often, involves successful entrepreneurs in the development process. There is, as yet, no association or conference that is recognized as a forum for faculty in this field so these contacts are taking place informally and piecemeal at programs such as Babson College's two invited conferences on entrepreneurship research and education or at a division gathering for those who happen to belong to the Academy of Management.

If it is true, as we now believe, that young, high growth companies are the primary source of job growth in this country and they are an extremely important part of the commercialization of innovation and of international competitiveness, then they deserve the same serious research, the same theoretical development, the same specialized textbooks as does the mature corporate sector of our economy.

Entrepreneurial companies to be formed around truly innovative technologies that come from university or national laboratory research face an especially daunting challenge and an especially high degree of risk. These research results and most of the people involved with them are very far from the market. To identify the economically attractive applications for early stage technologies requires a creative cast of mind and a resourceful diligence that is far removed from the marketing cases and statistical analyses of existing marketing textbooks oriented toward consumer products and well-documented markets.

Furthermore the R & D left to do after the basic research results have been established in the laboratory is usually substantial and expensive. No matter what the eventual return might be, most organized venture funds are not willing to invest in really innovative technologies in their early stages. They are looking for evolution, not revolution. Financing any startup is difficult; financing, in an entrepreneurial context, the kind of ventures that technology transfer policies want most to transfer is a real unresolved problem.

Although the federal commitment through Title IV should concentrate on training a core of business specialists versed in technology innovation and meeting the specialized marketing requirements I have mentioned the recognition of entrepreneurial business education that would come with the proposed Institutes and their assumption of a focal role at this early stage of development would have a significant acceleration effect on the entire range of entrepreneurship education.

Just as with technology transfer itself we have gotten far enough into it to know that it is easier said than done. Effective technology entrepreneurship is an extremely critical piece in our future competitiveness and we don't know everything we need to know about technology transfer or about entrepreneurship education. Title IV can certainly be a pivotal piece in the process if it is implemented thoughtfully and with realistic expectations.

Entrepreneurship Suffers Textbook Case of Neglect

By Calvin A. Kent

Since a course on economics principles is the first—or only—taste many students get of college-level economics, the process of entrepreneurship should be fully and accurately portrayed in its textbooks. Yet a survey of the 15 leading college economics principles texts, conducted by Baylor University's Center for Private Enterprise, indicates that entrepreneurship is a neglected concept in most of them.

Here are six fundamental concepts regarding entrepreneurship that rarely are integrated into the texts:

1. *Entrepreneurship as an economic resource.* Years ago most principles textbooks listed entrepreneurship or entrepreneurs as a separate "factor of production" along with land, labor and capital. But today, if mentioned at all, entrepreneurship is viewed as either a subset of "labor" or as a part of "human capital" and dismissed in a few sentences or, at best, a couple of paragraphs.

Often the entrepreneur is portrayed as nothing more than a manager, coordinating the use of the other economic resources. Only a few of the texts recognize that the entrepreneur is the innovative risk-taker in society. As such, he is a distinct factor in the productive process, seeing niches that others have overlooked and acting on those insights. Without this innovative, risk-taking propensity the other factors are basically sterile.

Few of the books make it clear that entrepreneurship is more than starting a new business. It also takes the form of "intrapreneurship," when the entrepreneurial event occurs within an existing organization. While in recent years several mass-market books have stressed that intrapreneurship is the key to the survival of corporate America, no college textbook conveys this insight.

2. *Entrepreneurs create and destroy markets.* At the heart of those incredibly dull chapters labeled microeconomics in most college textbooks is supply and demand analysis. The curves are derived and shifted, and equilibrium prices and quantities result. This is basically a static analysis. The student who has not been dulled into lack of curiosity may wonder what causes supply and demand to change, new markets to appear and old ones to disappear. That student will recognize that the market is dynamic, not static.

If the role of the entrepreneur in the marketplace is discussed at all in the texts, it is to mention that the entrepreneur responds to known price signals in the market, moving it toward equilibrium. In fact, entrepreneurship destroys market equilibriums by creating entirely new markets or market relationships through the introduction of products, services, processes or technologies.

3. *Entrepreneurship and profit.* While all the textbooks pay homage to the need for profits in a market economy, and a good number mention that profits are the incentive for the entrepreneur, most of the discussion focuses upon profits as a residual: what is left over after costs have been subtracted from revenues. This leaves the student without the understanding that entrepreneurial perception creates profits. But just as entrepreneurship creates profits, it destroys them. Joseph Schumpeter accurately portrayed the phenomenon of the "thundering herd" of imitators who compete away the profits made by the first entrepreneurs.

Very few principles textbooks communicate to the student that while important, profit is not the only motive for the entrepreneur. Autonomy and power are equally important, but these concepts cannot be easily integrated into the static geometry of the chapters on market equilibrium.

The texts also fail to note that if the entrepreneur's perception was a mirage, the entrepreneurial effort is not rewarded—as many defunct businesses bear testimony.

4. *Entrepreneurship and technological change.* Innovation is the entrepreneur's principal function in the market economy, but only a few of the textbooks tie entrepreneurship to innovation. While discussions of growth economics do include concepts such as technological change and technology transfer, they do not include their agent: the entrepreneur.

5. *Entrepreneurs create jobs.* In the macroeconomics portions of the textbooks there is usually a discussion of unemployment and how to cure it. The traditional answers are found in Keynesian or monetarist manipulations of the money supply, taxes and government spending. Many of the texts also mention the desirability of job training to deal with structural unemployment. But only one of the textbooks mentions that there is abundant research to confirm that the more dynamic entrepreneurial firms are the principal generators of jobs in the economy.

6. *Entrepreneurship in economic growth.* All of the texts contained chapters on economic growth. Many present the results of statistical analyses that try to isolate the factors that have caused some nations to grow and others to stagnate. These texts also include chapters on the underdeveloped countries with policy prescriptions for how their state might be upgraded.

The role of the entrepreneur as agent in the material progress of humankind is rarely mentioned. In fact, many of the texts assume that in underdeveloped countries there is an insufficient supply of entrepreneurial talent to propel them forward and so the government must plan. But in any society, no matter what its state of development, there is entrepreneurial potential that can be unleashed by a free-market structure. The growing literature indicates that what is restricting economic growth are government policies, both in the developed and the underdeveloped world, that restrict the entrepreneur.

One surprising finding of the survey was that entrepreneurship is as incompletely covered in the newer "free-market" textbooks as it is in the more traditional "Keynesian" ones. Three of the standard Keynesian texts do the most comprehensive job of covering the topic.

Economics educators need to rethink what is included in the principles course. If they integrate entrepreneurship, their students may find economics relevant to the real world after all.

Mr. Kent is professor and director of the Center for Private Enterprise at Baylor University in Waco, Texas.

Exhibit 1

Senator **Domenici**. I talked with the distinguished chairman just as he left, and I want to make a proposal without attempting to be arbitrary.

The given is this hearing will have no one appear to ask you questions at 4:30, and that normally means the committee is adjourned. I assume that none of you would want to go on without us here, so I would like to suggest that we attempt to expedite.

We are very sorry about this, but we have a bill on the floor, and we have George Shultz briefing the Senators at 5:00 on something that must be rather important. For all of you, I guess you know there is nothing more important than the Gramm-Rudman-Hollings reinstitutionalizing of the automatic trigger, and that is in the final stages of negotiation. I do not want to ask you how I should vote because I think I already know what you all think.

I think we ought to ask the four remaining witnesses if we could get your statements in the record, if you would agree to summarize your remarks by stating the most succinct things you have to say about this approach, and then if we have no questions today we will submit detailed questions to each of you that you can answer, say, in ten days if that makes sense.

Can we do it that way? Let us then try. Why not attempt, at least, in a minute or two to state your principal concerns, if you could have them both positive and negative, but if they are all concerns, that is alright with me.

Let us start with you, Dr. Cantor.

STATEMENT OF DR. CHARLES R. CANTOR, PROFESSOR AND CHAIRMAN, DEPARTMENT OF GENETICS, COLUMBIA UNIVERSITY

Dr. **Cantor**. I think I am here to give you the view from the trenches, because my collaborators and I are actually involved in trying to map part of the human genome. I think our major concern is that the project as a whole needs management.

I feel very much like in the early stage of constructing railroads in the United States, each company would use a different gauge and different equipment, and some routes would have many trains and others none. It is really the same with the genome. It is not a uniform coverage. It needs to be coordinated. Certain materials need to be prepared and provided centrally, and for this I think no existing structure is quite up to the task. We need something new.

I think the importance of the project is paramount. It can be done. It almost certainly will be done, and it is as guaranteed as anything I have ever seen in science to provide useful fallout.

I think the one point I would like to reflect which has not been mentioned by anybody before is a component of this project that needs to be developed is training. One of the problems we may have in trying to carry it out, especially in competition with activities in Europe and Japan, is a lack of master's level skilled technicians and a lack of respect for such people in biotech.

I think it is important to try to develop this as a component of the project, and I actually think the project is sort of an idea forum in which to carry out such training.

[The prepared statement of Dr. Cantor follows:]

Written statement: from Dr. Charles R. Cantor on S. 1480
Submitted to Senate Subcommittee on Energy R&D, 9-17-87

A project to map the human genome is already underway in many individual research laboratories, both in the U.S. and abroad. Because of the size and complexity of the project, special mechanisms would be very valuable to fund it, to focus it, to accelerate it, and to insure the U.S. retains the central role, both in carrying out the project, and in deriving the scientific and technological benefits from it.

The recent explosion of interest in the human genome project has been fueled by the development of a number of new scientific tools. These include methods for handling truly giant DNA molecules, enhanced methods for finding human genes, especially those important in diseases, and greatly enhanced methods for determining DNA sequences. The vast majority of these new tools are the product of basic research advances in U.S. laboratories. The new methods are already in widespread use throughout the world. To maintain our own dominant position in biomedical research and biotechnology, we must be in a position to play the major role in using these new methods to map the human genome. In the process, a number of important biological findings will be made, and a number of powerful new tools will be developed. Together with the incredible store of basic knowledge about our genome that will unfold, these advances will form the centerpiece of biotechnology of the next century. Our current focus is the 99.9% of the genome that is similar in all individuals. This is what endows us with all of the properties we think of as human. It remains for the future to explore the large number of genome differences which distinguish each of us from another, and also which are reponsible, ultimately, for most human diseases.

The scale and expected duration of the human genome project far exceed typical biomedical research programs. This, plus the central importance of the project, encourages the creation of new mechanisms to support and coordinate the effort. I see these mechanisms playing at least five key roles. Each of these requires a program overview that goes beyond individual laboratories or institutions. Each offers special opportunities for coordination among university laboratories, national laboratories and private industry.

1. Enhanced support is needed as soon as possible to allow our Human Genome Project to keep pace with ongoing and expanding efforts elsewhere. This support must complement, rather than replace, ongoing traditional biological research projects relevant to the overall long term objectives of the Human Genome Project. These short term programs need to thrive if the information derived from the longer range program is to achieve anywhere near its maximum impact on future biomedical research and development.

2. Improved facilities should be created for collection,

production, and distribution of key biological materials needed for the project. For example, the leading position of the U.S. in discovering and then manufacturing a class of enzymes called restriction nucleases has been a major catalyst in both basic and applied research in recombinant DNA. I believe that stocks of human genome material, including cell lines and DNA probes, will play a similar role in the future.

3. Long term support is needed for groups of researchers involved in major mapping efforts, and coordination of these efforts is needed to optimize technology and infomation transfer among them. The long term suport is needed to encourage some talented scientists to embark on a project whose goals are one to two decades off, rather than continue to be seduced by the more immediate rewards of traditional biological research. It will also encourage the development of new, more powerful methods rather than just the application of existing methods. Ultimately, coordination and new methods will lead to tremendous savings in the overall cost of the project.

4. Improved means are needed for the collection, analysis, and distribution of data derived from the human gene map. This endeavor requires a new interface between biology and advanced computing tools that is sure to produce important advances in research and technology.

5. Biotechology training programs should be established, including a special focus on training masters degree level skilled technicians. The current lack of such individuals in the U.S. is a serious impediment. Once trained they will play a major role in the human genome project, using a constantly changing blend of new biotechnology, instrumentation and computing. Skilled staff must constantly develop along with the new methods. They also must have a sufficient appreciation of the long range importance of the project to remain dedicated and motivated. Once trained, such staff will also be able to fill serious present and future needs in the biotechology industry.

The considerations discussed above, make me strongly in favor of the establishment, by S.1480, of a National Policy Board, to coordinate activities of different U.S. agencies in the human genome project, through its oversight of the proposed Human Genome Consortium.

Some past traditions in human genome research, and the potential health and economic importance of recent or future findings, have led to obtacles in the free exchange of materials and information relevant to mapping particular genes or chromosomes. For the overall Human Genome Project to be effective, there is a special need to encourage much more rapid sharing of materials and information among participating laboratories. I support the notion of the Consortium created by S.1480, since I think this will help expedite such coordination. Of course, a mechanism must be found which does not compromise the protection of proprietary information, so critical to ultimate delivery of the benefits of the new discoveries through better diagnostic and therapeutic products.

Several aspects of the Human Genome Project make it unique among large scale research programs.

1. It is an exploration of finite extent. There will only be one human genome project. We seek to acquire a very large amount of information, and the tools to use that information, but the end of the search is fairly well defined

2.The project is naturally divisible into a large series of parallel efforts. But these must be well coordinated. Indeed, the genome project is sure to be an international one, since significant efforts in an number of other countries are already ongoing.

3. There is a real economy of scale through the establishment of standard materials and centers for their distribution. Through such resources, and with the rapid transfer of technology and information, many potentially redundant or ineffective projects can be redirected along more productive lines.

For all of these reasons, it is imperative that we move forward as rapidly as possible to expand and coordinate onging efforts in the U.S. and accelerate the creation and integration of additional efforts.

Senator DOMENICI. Thank you very much.
Dr. Mendelsohn.

STATEMENT OF DR. MORTIMER L. MENDELSOHN, ASSOCIATE DIRECTOR, BIOMEDICAL AND ENVIRONMENTAL RESEARCH, LAWRENCE LIVERMORE NATIONAL LABORATORY, AND CHAIRMAN, HEALTH AND ENVIRONMENTAL RESEARCH ADVISORY COMMITTEE, DOE

Dr. MENDELSOHN. I would like to bring you the view from one of DOE's national laboratories. I am not going to give you the background. The arguments are really before us. I think the two agencies that we are discussing, NIH and DOE, as potential leaders of this effort have remarkably complementary styles, significantly different complementary styles.

I think the genome initiative needs both styles. The NIH style is needed to involve the broad scientific community in the innovative research for opening up the genomic technological opportunities.

The DOE style is needed, I think, to organize the multiplicity of ideas and experts that will come out of that into a hardened, targeted, production oriented national effort. In the later stages, DOE must orchestrate many production facilities into an efficient, thorough coverage of the genome.

NIH, I think, has the responsibility to weave the plethora of results back into the scientific and medical community.

We need them both. We need them to work as equal partners. We need each doing what it does best, each somehow appropriately funded and each put into a frame of mind where they will cooperate and bring the other government agencies into this act.

Now, how to do that and who should do that, certainly Congress and the executive branch have a role in this. I hope we can get the agencies to cooperate and come to this levelheadedly, but if not, if there is not to be a lead agency in that kind of cooperation, I think that technological coordination is the most important element of this, and at the moment DOE is the one that can do that.

Now, I would like to make one other point about this legislation. We in the field thoroughly support it. I am a little puzzled about why we are seeing the reluctance here in Washington, but we think it is important to establish this mandate. We are having a lot of trouble with long-range planning, with any sense of scale, with who our partners ought to be, how to commit to them.

All of these kinds of things are hard to do without having this thing firmly in place within the government. So I strongly support the arguments we were making earlier.

Regarding the technology transfer, we strongly support that also. We are having a very difficult time, try as we might, to do technology transfer under the current climate in DOE. The problem is not at the top. The problem is down in the bowels of DOE, and it is extremely difficult.

There is one issue of property rights that I would like to bring up, because in our zeal I hope we do not overdo this. I personally think the ordering, the sequences that come out of this effort, belong in the public domain. They are public property. I do not think they should be controlled or released slowly in order to allow commercial application.

There is plenty to commercialize here, I think, in the way of technology development, and I am all for that; but for goodness sake, let us keep the genome as something public. I hope S. 1480 will be clear on this.

[The prepared statement of Dr. Mendelsohn follows:]

STATEMENT OF MORTIMER L. MENDELSOHN

ASSOCIATE DIRECTOR
in charge of
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and

CHAIRMAN
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DOE

before the

SUBCOMMITTEE on ENERGY RESEARCH and DEVELOPMENT
of the
SENATE ENERGY and NATURAL RESOURCES COMMITTEE

SEPTEMBER 17, 1987

Mr. Chairman and Members of the Subcommittee:

I speak to you today in two roles: first as an Associate Director of a National Laboratory heavily involved in the DOE effort to clone and order large fragments of the human genome and in the NIH effort to map and apply human DNA probes; and second as the Chairman of HERAC, the DOE advisory committee on health and environmental matters, and the source of a recent subcommittee report on the "Human Genome Initiative" strongly supporting the initiative and DOE's role as a major player.

The purposes, benefits and technical nature of the genome project have already been well described by several speakers. On this subject, suffice it for me to state my conviction that the time is right for the Nation to launch this effort, that for biology and medicine the genome initiative will lead to an incredible leap forward, and that for the Nation there will be major internal savings in health care as well as external benefits in technological leadership and economic competitiveness.

My time with you is best spent discussing several issues bearing on how to organize this new effort.

The human genome initiative is extraordinary on several counts: its sheer magnitude, its need for a large up-front investment, its multidisciplinary nature, its heavy involvement of multiple government agencies, and its open-endedness. All of this requires a carefully designed, appropriate administrative structure. It is my sense that the intense national debate about this project has quite rightly shifted in emphasis from whether it should be done to exactly how to do it. The time is fast approaching when organizational decisions must be made if indeed the initiative is to get a healthy and competitive start.

NIH and DOE are the two major agencies contending for leadership roles in the genome initiative. Each brings to the effort a distinctly different style of management. The NIH extramural programs are structured into an investigator initiated, externally peer reviewed, research grant mechanism. This system involves a minimum of central organization or coordination. The grants tend to be small, self-contained and self-managed, and the overall process is strongly oriented toward the even-handed elicitation and funding of imaginative, creative, bright new ideas in biomedical science. In the context of the human genome initiative, the NIH system is ideally suited for localizing and sequencing one gene at a time, for conventional mapping procedures which require relatively small independant committments of effort, and for generating innovative strategies in support of the larger aspects of the overall project. However brilliantly it may perform in general medical science, the traditional NIH mechanism is poorly designed for sustained and multidisciplinary projects, for instrumentation development and production, and for the large scale and active coordination that will be required for efficient ordering and sequencing of the human genome.

In contrast, the DOE research is characterized by central coordination and active management. DOE operates primarily through interactive contracts geared to large-scale, long term projects. It focusses primarily on its field laboratories, the National Laboratories, which are stable, superbly equipped research environments designed for multidisciplinary, large, longterm projects in a setting that encourages engineering development, large computational facilities and appropriate support for cutting edge technically oriented science. University and industrial involvement traditionally emanates directly from DOE or secondarily via the National Laboratories through subcontracts. In the context of the genome project, DOE has a programmatic need for and good track record in genetic and molecular biological research, and an excellent reputation for accomplishing highly complex, expensive, long term objectives. However because of its centralized management style, DOE is not well suited for a broad, diffuse, investigator-initiated promotion of new ideas. Also, given its relatively narrow mission, DOE has a limited ability to lead the broad sweep of biological and medical developments that will soon be stemming from the genome inititiative.

Interestingly, in genome related work already underway, the two agencies are already behaving consistently with their traditional pattern. NIH has heavily supported basic molecular genetics and the development and application of conventional mapping using RFLP, linkage and in situ hybridization. While DOE has supported chromosome purification, the production of human chromosome-specific gene libraries, ordering of DNA fragments, and data-basing of DNA sequences (with NIH support). Of the remaining roles in the genome initiative, the development of new sequencing methods is scientifically open and needs a broad input from scientists in general, in the manner of NIH; while the instrumentation necessary to apply the definitive sequencing methods, as well as their application in a coordinated production mode, are typical DOE roles. The massive computational task including the central repository, a national network for users, and interfacing to other data-bases is again a natural DOE role, but it should be supplemented by much innovation through NIH mechanisms to create the manipulative skills needed to interpret DNA sequences.

It is my view that a successful genome effort requires the full involvement and cooperation of both agencies in a structure that brings out what each agency can do best. NIH needs its own funding and style in the early stages to involve the breadth of American science with the innovative, basic research needed to optimize the genome initiative, and in later stages to integrate into contemporary genetics and medicine the huge amounts of information that will soon be forthcoming. DOE needs a clear mandate and the associated funding to coordinate and drive the necessary technological development and the large-scale production phases of the initiative. Somehow, whether through Congress or the Executive Branch, a design must be found that will accomplish this with minimal layers of management and with responsibilities and accountabilities appropriate for each agency. Other relevant players, such as NSF (technology development), Howard Hughes Medical Institute (basic genetic research, databases), and Industry (technology development, production, applications) must be woven into this fabric in a constructive, practical way.

The legislation we are considering today only deals with half of this administrative problem. However, I believe that it is a very promising step toward improving the way that DOE can play its half of the leadership role. In my remaining comments, let me focus on this.

In many respects DOE is able, with present powers, to play its role in the genome initiative. Our own experience at Livermore is a clear demonstration that DOE knows how and when to delegate responsibility, and that the National Laboratory system is able to play its role creatively and effectively. Livermore has a 5-year, close collaboration with Los Alamos in the highly successful National Laboratory Gene Library Project. Based on this capability to clone DNA fragments from purified specific human chromosomes, Livermore has, over the past two years, developed a broad approach to physical ordering of the genome. Our confidence in the overall strategy, our mathematical modeling, and our array of available and new molecular technology has us poised to begin an 8-10 person year effort over the next two years to order chromosome 19. What we have done is well known to the relevant scientific community, and has been received very positively.

That is the plus side. But on the negative side, Livermore is making this heavy committment with much uncertainty about how it will fit into the national effort. DOE is doing its best to put into place the necessary superstructure to carry out the genome initiative, but until this is accomplished, and until the national priorities, including DOE's specific roles, are better defined, we in the field remain uneasy and unnecessarily preoccupied with uncertainty about future role, risk of committment, scale of our own effort, realistic planning beyond the current year, and clear knowledge of who our partners will be and how we should relate to them.

Also on the negative side, we believe firmly in technology transfer and industrial partnerships, and we are having great difficulty accomplishing this with existing DOE procedures. The problems take many forms: unrealistic delays in DOE decisions on patents and cooperative agreements, absence of the already legislated mechanisms of technology transfer in the master contract that defines how this laboratory operates, and pockets throughout DOE staff of old-style attitudes and individuals who refuse to cooperate with currently mandated procedures in technology transfer.

Thus we in the field welcome the intentions of S 1480 to establish DOE's role in the genome initiative and to free the National Laboratories from technology transfer constraints. We have found ourselves increasingly in accord with the detailed procedures in the Bill as they have been successively amended. But we also realize that DOE has some legitimate reasons for objecting to current wording. Knowing full well that ultimate success is optimized by having all parties in accord, we would encourage DOE and Senate staff to work out their differences in a constructive rather than antagonistic mode.

One final point about technology transfer is worth emphasizing here. This deals with the issue of open versus closed data in the genome initiative. Ideas related to instrumentation, novel methodology, and spin-off applications should be protected as needed for full industrial cooperation and involvement. It is precisely toward this end that the technology transfer, industrial partnership aspects of S 1480 are so important. However, I believe strongly that the actual genomic maps, orderings and sequences should be widely and immediately shared in the public domain. The "book of man" must not be private, copyrighted, censored or in any way restricted. All players in and out of the initiative should have equal access to this type of data, and those playing within the initiative should be required to agree to and abide by this stipulation. I would hope that S 1480 would leave no ambiguity on this point.

In closing, let me thank you for this opportunity to comment on what for me is the most exciting scientific development of my lifetime.

Senator DOMENICI. Thank you.
Dr. Miller.

STATEMENT OF DR. WARREN F. MILLER, JR., DEPUTY DIRECTOR, LOS ALAMOS NATIONAL LABORATORY

Dr. MILLER. Mr. Chairman, first let me say that I am going to make only a few comments. First, the United States has an absolutely superb basic research program in human genetics led by the National Institutes of Health with contributions from the National Science Foundation, the Department of Energy and others, and the coordination of those agencies by a committee or council is certainly appropriate in that research program.

I agree with my colleague, Dr. Gilbert, that there needs to be established goals for this more, what I refer to as, goal oriented part of the program to develop tools. Those tools are large sequence data bases and physical maps. Those tools are to be used by that research community in the ways that we have described.

The third point is, in my view, the Department of Energy and its laboratories have indicated they know how to conduct large scale goal oriented multidisciplinary projects, and I believe that goal oriented component, therefore, of this effort ought to be led by the Department of Energy. It ought to utilize its laboratories as well as key capabilities in universities and in industry and, as I said before, the National Institutes of Health and industry and others ought to be the users of that information.

[The prepared statement of Dr. Miller follows:]

U.S. SENATE
COMMITTEE ON ENERGY AND NATURAL RESOURCES
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

HEARING ON

THE HUMAN GENOME INITIATIVE

Statement by
Dr. Warren F. Miller, Jr.
Deputy Director
Los Alamos National Laboratory
September 17, 1987

I. UNDERSTANDING THE HUMAN GENOME---THE CHALLENGE

A. Status of Life Sciences Research

Throughout history, humans have vigorously sought to fully understand themselves and their environment. The progress since World War II toward fulfillment of these dreams has been staggering. We have experienced remarkable discoveries and have developed exciting new insights derived from the efforts of research scientists. The biological sciences have certainly been no exception.

We are in the midst of a revolution in biology that had its beginnings some 40 years ago (see Appendix A) with the emergence of the field of molecular genetics. The discovery that genes are made of the linear polymer deoxyribonucleic acid (DNA) was followed by remarkable insights into the chemistry, biological function, and structure of genetic material. There has been a concomitant increase in understanding the profound role of genetic material in human development and aging and in human susceptibility to diseases that heretofore were considered to have no genetic component in their causes. We now understand that the genetic material in each human (the human genome) is a set of complete instructions for the development and function of the human body, and those instructions have a profound impact on how well and how long each individual will live. The detailed understanding of that genetic material is arguably the most important scientific challenge facing mankind.

The best approach to gaining a detailed understanding of human genetic material is to systematically increase our knowledge of the chemistry, structure, and biological function of the human genome. Discoveries in each of these areas lead to insights in the others. Through past efforts, we now know that each human has two sets of 23 chromosomes. Each set consists of 22 autosomes plus 1 female or male sex chromosome, for a total of 24 distinct chromosomes---22 autosomes, 1 female (X), and 1 male (Y). The chromosomes contain an unknown number of genes: estimates range from 20,000 to 200,000 or more. Genes are simply portions of chromosomes that control the production of specific products, such as proteins, each having a specific, and generally crucial, function.

Chromosomes and their genes are composed of sequences of four specific chemical or nucleotide bases that appear in pairs. The entire human genome is composed of approximately three billion base pairs. We now know that the sequence of these pairs defines the genes and their operations and therefore determines the complete set of human instructions.

Scientists have so far located and sequenced on the order of 500 genes. A gene sequence may permit definitive diagnosis of disease associated with that gene, and more generally, sequencing provides a better understanding of the gene's biological function. Single-gene research has identified changes and aberrations in genetic material heavily implicated in diseases with a strong tendency to be inherited. Human geneticists have identified over 3,000 genetic diseases, including cystic fibrosis, muscular dystrophy, sickle-cell disease, hemophilia, and Huntington's disease.

Along the way, bioscience researchers have developed a set of remarkable new biotechnologies. Examples are restriction enzymes that chemically cut DNA strands at specific physical locations and biological methods to construct recombinant DNA molecules and to clone or exactly copy strands of DNA.

Our present knowledge of genetic material, although immense compared with our knowledge of four decades ago, is extremely rudimentary compared with our understanding of physical materials, such as metals or ceramics. This difference is due, among other reasons, to the remarkably complicated interactive processes of the human body and to the difficulty of conducting research using human subjects. In commenting on the current state of our understanding, a distinguished advisory committee to the Department of Energy (DOE) recently stated:

"Our knowledge [of the human genome] is equivalent to that of 15th century anatomists who knew about the major bones and organs, but knew very little about their functions. The significance of most vital organs, including obvious ones such as the liver and pancreas, or small ones such as the pituitary and the adrenals, was completely unknown. Most important, even the simplest concerted functions of the body, such as provided by the circulatory system, were not mapped."[1]

The fruit of past research into the chemistry, structure, and function of genetic material has been a profound increase in understanding human genetics, a better understanding of human heterogeneity and many diseases, and the development of powerful new tools for biotechnology. During the course of this work, the location, sequence, and analysis of a very small fraction of the tens to hundreds of thousands of genes has emerged. Paradoxically, the results have given us enough insights to make us clearly appreciate how little we know and to demonstrate the immense value of sequencing and understanding the complete human genome.

B. Achieving a Complete Sequence of the Human Genome

There are two fundamental approaches to achieving the goal of a complete sequence of human genes. The first is to continue the approach presently used. The successes discussed above were achieved through the peer review/single investigator basic research system, which is largely university based, although government-operated, industrial, and the DOE National Laboratories also conduct significant basic research. Typically, this basic research is conducted by small teams composed of faculty/scientists, postdoctoral fellows, students, and technicians. Such teams often spin off biotechnology companies and stay in close contact with them.

This first approach uses bench-scale technology to locate, clone, and sequence specific genetic material and to research biological function, chemistry, and so forth. Sequences are then provided to national repositories of data, specifically GenBank maintained by Los Alamos National Laboratory (see Appendix B).

The problems with continuing this approach without enhancing it are the time it will require and the high cost. If we continue with present-day technology, without a concerted program to improve it, and if we assume the sequence capability available will be only that needed by the small research team, then an estimate of the required effort approaches 30,000 man-years. This estimate is based on the fastest rate at which a trained technician can sequence base pairs, about 100,000 base pairs per year.[2] Also, because present technology yields a cost of approximately $2 per base pair, and assuming both DNA strands would be sequenced, the total effort could cost $6 billion,[1] and probably it would cost much more because of the duplication of effort. Depending on the technical manpower assumed, the effort could easily take 50 years. More likely, it will never be done without a more-focused effort.

Fortunately, there is another approach. Technologies now becoming available from other disciplines have the potential of profoundly affecting the sequencing effort. New automated and robotic technologies could dramatically improve sequence productivity by allowing automation of current methods. The Japanese are conducting a national project to achieve sequences of 300,000 to 1,000,000 base pairs per day by automating current technologies.[1] Additionally, completely new sequencing technologies are possible. Laser-based approaches being investigated at Los Alamos, for example, could potentially reduce costs from $2 to 1¢ per base pair. Further, if computational methods of pattern recognition and artificial intelligence are applied to the vast computer data base housing the sequenced information, the data base could become a significantly more powerful and user-friendly tool. Thus, a second approach to achieving a complete sequence would be to augment the present decentralized approach with a goal-oriented, more-focused, applied research and technology development program, leading to a complete sequencing effort.

II. THE HUMAN GENOME INITIATIVE---THE RESPONSE

The time is ripe to embark on a Human Genome Initiative as a major and focused effort to generate a complete sequence of the human genome. The deliverables from the Initiative should include generic data bases served by powerful computer software to allow user-friendly access and data analysis. Additionally, mapped and sequenced DNA fragments from clone libraries should be provided to the research community. A crucial by-product from the Initiative should be advanced biotechnologies for commercialization by U.S. industry, directly strengthening economic competitiveness. Thus, the Human Genome Initiative is designed to develop and provide tools---data bases and clone libraries---as well as technology spin-offs. The larger task of human genetics is to relate and apply these tools to understanding the development of the human organism, to understand diseases, to classify human characteristics, and to explain physiological function. This larger task requires that a strong program of basic research be conducted both while the Initiative is being pursued and even after the Initiative ends.

The United States conducts an outstanding basic research program in human genetics with a well-respected peer review system. The program is led and largely funded by the National Institutes of Health (NIH). This program provides much of the demand for the deliverables of the Initiative and also yields data that must be incorporated into the data bases and libraries compiled through the Initiative. Congress must continue to appropriate the financial resources for this strong basic research effort to the specific funding agencies (for example, NIH), and the specific agencies must continue to establish and control their research policies and procedures. This effort should not be managed under the auspices of the Initiative. To ensure the success of the Human Genome Initiative, however, the Initiative must remain cognizant of the basic research program. Specifically, it is important to try to ensure against unnecessary duplication of effort and to ensure that sequenced data and cloned fragments emerging from basic research are merged into the common data base and clone library. Additionally, the ongoing mechanisms for coordinating research related to human genetics must continue under the auspices of the Domestic Policy Council.

A. Objectives

The principal objectives of the Human Genome Initiative are

1) to conduct a goal-oriented Human Genome Project that will physically map the human genome; provide advanced mapping and sequencing technologies; eventually sequence the entire human genome; and provide appropriate reference biological materials (clone libraries) and data bases for use by the research community. Such a focused effort must be run by an agency with experience in managing large, multidisciplinary, goal-oriented projects. The Department of Energy is the best agency for this responsibility.

2) to facilitate and accelerate the transfer of technologies developed during the conduct of the Initiative to U.S. industry for commercialization.

B. The Human Genome Project

The first objective, the goal-oriented Human Genome Project, is envisaged as a long-term, high-technology effort, requiring the participation of multidisciplinary talent and several institutions. To be successful, effective program management of the Initiative is imperative. Management includes program planning, allocation of resources to the participating centers, assessing technical progress, tracking and projecting costs, establishing milestones, and generally ensuring accountability. The Project requires identified funding as a budget line item.

The immediate goal of the Project is to produce a physical map of the human genome. A physical map is a complete set of DNA segments arranged in order that can be used as reference for the location and study of genes. Although somewhat cumbersome at present, technologies are available to construct such a map. Already, Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Columbia University, for example, have begun efforts to map chromosomes 16, 19, and 21, respectively.

The physical map will allow a subsequent sequencing effort to be much more productive by helping to identify the portions of the human genome of most immediate interest to researchers, the portions therefore having high priority for sequencing. Additionally, a physical map would be significant in its own right. The physical map will be compared with the genetic map, a map based on the frequencies with which specific DNA sites are associated with specific traits (e.g., diseases). Comparison of physical and genetic maps will provide a more rational basis for understanding the genetic component of major chronic diseases or human predisposition to diseases.

The applied research portion of the Human Genome Project, designed to develop advanced technologies for mapping and sequencing, is crucial to reducing the cost of a systematic sequencing effort. Research and development on automation, mapping and sequencing technologies, systems engineering, and the handling, analyzing, and accessing of sequence data are all important. The success of the technology development program is required to enable a cost-effective, systematic sequencing effort. Thus, a decision to proceed with a large-scale systematic sequencing effort will await results from the technology development effort. The Project, however, will certainly involve near-term sequencing of the most important DNA fragments.

The results of the Initiative will be immediately available; there are no multiyear waiting periods for payoff from investment in human genome research. Ordered sets of DNA clones will become available as soon as they are produced. Data libraries will generalize the experiences of GenBank and will ensure that data become available as they emerge from mapping and sequencing efforts (both from small research groups and from the larger, centralized effort). Additionally, new biotechnology methodologies will be available for commercialization as they are developed.

The Human Genome Project should be led by a management structure (discussed below) that will guide a programmatic effort conducted in universities, industries, and National Laboratories. The Project also must interface with the basic research effort to assure that results of that research are incorporated. The details of the Project elements and assignments of responsibilities must be worked out, but basically, multidisciplinary centers should be assigned responsibility for aspects of the Project objectives. These centers must have the capability of mounting talented, multidisciplinary teams of scientists, engineers, and technicians to tackle complex applied research problems, as well as to contribute to basic research. Additionally, small teams in universities and industry may contribute novel ideas in such areas as sequencing and mapping technologies.

Several of the Department of Energy's multiprogram National Laboratories are especially suited to perform as Centers of Human Genome Studies. DOE recently named two such Centers, Los Alamos and Lawrence Berkeley Laboratory. The research activities of the National Laboratories include general science, energy science, and defense-related applied research programs. They have a track record of successfully bringing together multidisciplinary teams of physicists, chemists, computer scientists, engineers, and bioscientists to attack complex problems. These Laboratories have large user facilities, such as particle accelerators and coherent light sources, first-class research equipment, incomparable computer facilities, and excellent research and support staffs. Of particular relevance to the Initiative, the National Laboratories have conducted extensive research on the human health consequences of both nuclear and nonnuclear energy technologies, including the consequences for human genetic material. Recognizing the strength of the biology research capabilities of the Laboratories, the NIH provides basic research funds to several of them on a reimbursable basis. For all these reasons, Centers for Human Genome Studies should be identified and funded at appropriate National Laboratories participating in the Project.

C. Technology Transfer

The United States has conducted a basic research program in the biological sciences that is the envy of the world. New biotechnologies, such as recombinant DNA, have emerged from that U.S. research effort. The result is a growing biotechnology industry. The revolution has also affected the pharmaceutical industry, which uses increasingly more rigorous scientific approaches in developing its products. However, competition from other countries, principally Japan, is increasing dramatically. The United States must take maximum advantage of technological spin-offs from the Human Genome Initiative.

The second principal objective of the Initiative must be to rapidly transfer technologies emerging from the Human Genome Initiative, as well as to assure U.S. industry of rapid access to the data and clone libraries for its own research and development needs. New technologies that can be commercialized will likely be developed in the Human Genome Project, even though the principal motivation for their development will be the mapping and sequencing effort. Additionally, technologies for commercialization will no doubt continue to emerge from the basic research effort. Industries interested in commercializing these technologies must define the market and guide (as well as fund) product development for these markets. The Initiative must allow industrial concerns to fund the program participants to conduct research in generic technologies as well as to perform proprietary work to help modify technologies into forms that might be marketable. A more detailed description of the potential role of National Laboratories in technology development for the private sector is presented in Ref. 3 for the case of high-temperature superconductors. Finally, the Initiative should include an effort to identify and eliminate any unnecessary hindrances to technology transfer.

D. Oversight of the Human Genome Initiative

A National Policy Board should be established to provide coordination and oversight to help accomplish the objectives of the Initiative. This Board should be composed of distinguished leaders from involved government agencies (including NIH), private foundations, industry, and universities. The Board must establish policies, strategies, and goals and oversee activities of the Initiative. The Board should continue to be cognizant of the relevant genetics basic research programs administered by NIH, the DOE, and NSF, as discussed above. Data emerging from the basic research program must be expeditiously included in central data libraries, and data from those libraries developed by the Human Genome Project must be available to basic researchers. Because the Board will have no authority over research programs in the agencies, cooperation will be of paramount importance.

The Department of Energy is the appropriate agency to direct the Human Genome Project. The Department has an excellent track record in managing long-term, multidisciplinary technological programs. It makes use of the capabilities of universities and industrial contractors in carrying out goal-oriented programs, but the major source of its technical strength resides in its National Laboratories. Therefore, the National Policy Board, which oversees the Human Genome Project as well as the technology transfer effort, should be convened by and should report to the Secretary of Energy.

The technologies developed in the conduct of the Initiative, as well as the sequence data, will be extremely important to industry. These technologies include those emerging from the Human Genome Project as well as those developed in the basic research program brought to the attention of the Board. Thus, the Board must include industrial representation and must attempt to aggressively pursue ways to enhance the transfer of technologies. The Director of the Office of Energy Research (OER), who should be a Board member, will be directly responsible for administering the technology transfer aspect of the Initiative.

The Human Genome Project Director (PD) should be the Director of the Office of Health and Environmental Research (OHER) in the Department of Energy. The PD should be responsible for the successful conduct of the Project, including all aspects of program management. In carrying out Project goals, the PD should utilize the capabilities of National Laboratories, universities, foundations, industry, and other Department of Energy offices. The PD receives policy oversight from the Board to ensure that the Project proceeds in an expeditious manner toward meeting the national objectives.

In managing the Project, the PD must continually be cognizant of the technical input of industry and of universities. To ensure the best in scientific and technical quality, he will require the best advice. Therefore, a scientific advisory committee composed of distinguished academicians and industrial scientists should advise both the PD and the Board and also assure appropriate peer review of research directions and activities of the Project.

It is important to reiterate that the Department of Energy should be responsible for providing the *tools*---data bases and ordered clone libraries. The larger role of application of the results to biology and biomedical science must continue to be led by the National Institutes of Health.

III. SUMMARY

A national undertaking to understand the human genome offers great hope of unraveling the physiological mysteries of human life. The ultimate benefit is to provide unprecedented insight into human diseases and improve human health.

At present, the scientific community lacks the necessary technological tools for a concerted effort to map and sequence the human genome on a massive scale within a reasonable time frame. Creating these tools and providing the complete sequence require a large-scale, multidisciplinary effort involving government agencies, foundations, National Laboratories, universities, and private industry.

Major elements of a Human Genome Initiative include conducting a Human Genome Project and facilitating technology transfer. The coordination of the national genetic basic research program among agencies will be instrumental to the success of the Initiative. Specific goals of the Human Genome Project are to physically map the human genome, to provide advanced mapping and sequencing technologies, to eventually sequence the entire human genome, and to provide appropriate clone libraries and data bases for government agencies, foundations, universities, and industry.

A National Policy Board will oversee the efforts of the Initiative and provide policy guidance. It will remain cognizant of basic research results; oversee the progress of the Human Genome Project located in the Office of Health and Environmental Research in the Department of Energy; and facilitate technology transfer. The Project will be managed by the Department of Energy, and the Board will report to the Secretary of Energy.

REFERENCES

1. "Report on the Human Genome Initiative for the Office of Health and Environmental Research," U.S. Department of Energy, Office of Energy Research, April 1987.

2. "Report of the Santa Fe Workshop on Sequencing the Human Genome," U.S. Department of Energy, March 3-4, 1986.

3. Testimony of Siegfried S. Hecker, Director, Los Alamos National Laboratory, at the Hearing on High Temperature Superconductivity before the U.S. House of Representatives Committee on Science, Space, and Technology, June 10, 1987.

APPENDIX A

History and Status of Human Genetics---A Summary

Introduction

This summary provides an overview of the key discoveries and principles underlying the field of human genetics. Advances in our understanding of human heredity have depended on basic findings in related fields of cell and molecular biology and recombinant DNA technology. The summary highlights the contributions made to the biological sciences by the allied disciplines of physics, chemistry, mathematics, and computational science. Finally, the text describes our current knowledge of human genetics and looks toward the future---the potential for understanding in detail the organization and regulation of complex genomes and the way this knowledge will contribute to other areas of biology and the life sciences.

Historical Perspective

Gregor Mendel deduced the principles of modern genetics through observation of the inheritance of certain traits (color and shape) that resulted from his mating of carefully selected pea plants. In the publication of his work in 1865, Mendel proposed what we now call the gene concept of inheritance to explain the transmission of characteristics from generation to generation. Of course, the physical identification of genes was to come much later. Concurrent with Mendel's discovery, Francis Galton and Karl Pearson (English scientists) were working on mathematical methods for analyzing inheritance of complex human traits. Their inventions in the introduction of statistical methods to analysis of inheritance laid the foundations for the area of biometric genetics. Although Mendel's laws were articulated in 1865, they lay dormant until the turn of the century when they were rediscovered by three botanists, H. M. de Vries, K. E. Correns, and E. Tschermak. This rediscovery initiated an early revolution in genetics.

This revolution in genetics exemplifies the rapid advance in knowledge that occurs when key observations from diverse fields are brought together. During the nineteenth century, two German microscopists, M. Schleiden and T. Schwann, among others observed that plant and animal tissues were composed of individual, discrete units called cells. They proposed that these cells were the fundamental units of all plants and animals. Further, Rudolph Virchow, a German physician, proposed that cells arose from other cells by a process of cell division that ensured equal distribution of all cell components in the mother cell to the two daughter cells. More importantly, this fundamental structural unit was also suggested as the fundamental functional unit for reproduction; that is, the cell is the smallest unit of life capable of producing more life.

Within two decades after the recognition of the significance of cells as the fundamental units of life, Walter Fleming observed that in each cell nucleus, condensed bodies, called chromosomes, duplicate to form an identical set of chromosomes before cell division. During cell division one chromosome of each identical pair is distributed to each daughter nucleus. Consequently, the chromosome content of each daughter cell is identical to the chromosome content of the mother cell. In the early twentieth century, cell biologists such as E. B. Wilson, Th. Boveri, and W. S. Sutton, a student of Wilson, recognized the relationship between Mendel's laws and the movement and equal distribution of chromosomes during the formation of reproductive cells (eggs and sperm). These events provided the basis for identification of chromosomes as the carriers of genetic information. The first trait assigned to a chromosome was sex determination---a trait assigned to a single pair of morphologically distinct chromosomes designated the X and Y chromosomes, which appear as an XX pair in females and an XY pair in males.

Another landmark observation in the early revolution in genetics was reported by A. Garrod, a physician who identified a human inborn error of metabolism (alkaptonuria---a biochemical defect in the metabolism of amino acids, the building blocks of proteins [see below]) and related the pattern of inheritance of this disorder to predictions of Mendel's laws.

During the first decade of the twentieth century, studies of T. H. Morgan and his students on the inheritance of traits in the fruit fly, Drosophila, revealed the linear order of genes (the trait carriers that, as later discoveries proved, produced products such as proteins) along chromosomes. These conclusions were based on cross-breeding experiments using parental stocks (variants) having stably inherited traits. The variants arose spontaneously at low frequency. In 1926 H. Muller and L. Stadler independently observed that x rays increase the frequency of appearance of variants (or mutants). This discovery provided an important tool for geneticists to obtain a large number of mutants for breeding studies. Consequently, it was possible to map traits, or genes, rapidly, and by the end of the 1930s, over 1,500 genes were estimated to be located on the four Drosophila chromosomes.

In the first half of the twentieth century most of the basic principles underlying the science of genetics were discovered in insects and plants, the primary research tools. The morphological observation and characterization of chromosomes (the field of cytogenetics) continued to be applied in close association with breeding experiments to study the location, organization, and transmission of genes.

Although chromosomes had been identified as the carriers of hereditary traits, or genes, elucidation of the molecular nature of genes required contributions from chemists, microbiologists, and biochemists. Improvements in microscopy and the invention of the electron microscope permitted ever-higher resolution analysis of chromosomes, but the hope that these tools would make it possible to visualize genes sitting next to one another along the chromosome was not realized. Biochemical approaches to isolation of chromosomes from other cellular material, even though not producing pure chromosomes, permitted chemical analysis of the composition of enriched chromosome preparations. These analyses consistently revealed two major components of chromosomes---deoxyribonucleic acid (DNA) and a group of positively charged proteins, called histones, which, because of their basic chemical property, neutralized the DNA acidity. DNA had been discovered as a major constituent of the cell nucleus in 1869 by Frederick Miescher, a Swiss scientist. Cytological observation of the localization of DNA in chromosomes using microscopy was made possible in 1920 by the development of a DNA-specific dye by Robert Feulgen, a German chemist. The question as to whether the DNA or the histones carried genetic information was partially resolved by the observation that histones are absent in sperm, the male sex cells, where, in many organisms, the histones are replaced by smaller basic proteins, the protamines.

In 1944 the elegant experiments of O.T. Avery, M. McCarty, and C. MacLeod at the Rockefeller Institute elucidated the chemical nature of the genetic material. These investigators used a process called bacterial transformation (the conversion of a bacterial cell's characteristics to a set of new characteristics) to convert a nonvirulent bacterium to a virulent bacterium using the DNA isolated from the virulent bacterium. None of the other components of the virulent bacterium (that is, the polysaccharide or sugar-like components of the outer coat; the protein components; or the ribonucleic acid, a second form of cellular nucleic acid) were active in the transformation process. The role of DNA in carrying genetic information was confirmed in 1952 by scientists A. Hershey and M. Chase at Cold Spring Harbor. They showed that only the DNA entered a bacterial cell when the cell was infected by a bacterial virus.

The period immediately preceding and following World War II witnessed a rapid series of advances that led to the birth of a new discipline---molecular genetics---and paved the way for a revolution in human genetics. Definition of the chemical nature of the genetic material was a key step in the further analysis of the structural and functional features of the hereditary substance. Structural studies of DNA predated World War II. These early studies using electron microscopy and x-ray crystallography revealed that DNA is an elongated, unbranched chain. F. Crick and J. Watson used detailed x-ray crystallographic analyses of DNA coupled with the quantitative chemical analyses to predict the structure of the DNA molecule. The now-familiar helical, double-stranded, self-complementary structure revealed by their analyses represented a fundamental breakthrough in understanding the transmission of heredity. Each strand of the DNA helix is composed of a linear polymer of nucleotide bases (commonly known as A, T, G, C) linked by a series of sugar-phosphate bonds. The self-replicating capability of the Watson-Crick double helix was an inherent property of the postulated structure. This structure also provided a basis for understanding how changes in the DNA (mutations) could be inherited.

A Revolution in Human Genetics

While these seminal developments were taking place in allied fields, progress in the field of human genetics focused primarily on the biochemical and cytological analysis of hereditary defects. In 1956 the number of human chromosomes was correctly determined to be 46---22 pairs of autosomes found in both males and females, plus a pair of X chromosomes found in females or an X and Y pair found in males. The report of the normal human chromosome complement (or karyotype) provided the standard for detection of abnormal karyotypes. The stage was set for a new discipline, clinical cytogenetics.

The field of cytogenetics (the microscopic analysis of chromosomes) continued to undergo rapid evolution with development of new dyes or stains (for identifying specific r\ons of chromosomes), as well as with advances in microscopy, especially in the area of new instruments for detecting fluorescent dyes. In 1969 Caspersson made a major breakthrough in chromosome analysis when he developed a technique for reproducibly resolving chromosome substructure. This technique commonly known as banding uses a staining procedure to reveal alternating stained and unstained regions, or bands, along the length of the chromosome. The average human chromosome contains approximately 40 bands.

Developments in cytogenetics, together with advances in cell biology and biochemistry, led to discoveries and methods for assigning genes, or traits, to chromosomes. These achievements paved the way for construction of a human linkage map (the order of genes along the chromosome) using the techniques of somatic cell genetics (the study of inheritance of genetic traits in cells grown in culture).

While these revolutionary events were taking place in cytogenetics and somatic cell genetics, major developments in molecular biology and biochemistry had led to the breaking of the genetic code---a fundamental understanding of how genetic information is encoded in the DNA double helix. The early 1960s brought several breakthroughs in deciphering the genetic alphabet and the mechanisms involved in decoding the information contained in a DNA chain. The chain of nucleotide bases was decoded into a chain of amino acids comprising the gene product, an enzyme or a structural component of the cell.

In the process of unraveling these phenomena, a role for ribonucleic acid (RNA), the second type of cellular nucleic acid, was discovered. An RNA strand is copied (transcribed) directly from one strand of the DNA double helix under the control of specific start and stop signals in the DNA strand. The linear RNA strand is then decoded three bases at a time, sequentially along the chain beginning from a start signal. The machinery performing this decoding process (translation) recognizes each three-base triplet, or codon, and places an amino acid (the fundamental building block of proteins) in a linear sequence corresponding to the order specified in the RNA (and DNA) strands. The translation machinery also joins neighboring amino acids with covalent chemical bonds. Termination of translation is also specified by a stop signal in the RNA strand.

The start/stop signals for transcription are different from the start/stop signals for translation. The four nucleotide bases can be arranged in 64 different combinations of sets of three bases. However, only 20 different amino acids have been found in all proteins examined. This apparent paradox was resolved by the observation that several amino acids are encoded by more than one three-base codon. Furthermore, codons specifying start and stop occupy four additional codons. By 1966 the entire genetic alphabet had been decoded and the precise nature of the colinearity between gene and protein had been revealed. With only a few exceptions, the genetic code is universal among all species examined.

Although this primer greatly condenses and simplifies the evolution of knowledge about the storage and transmission of genetic information, an underlying theme should be noted---the importance of both conceptual and technological contributions from many scientific disciplines converging to answer fundamental questions about the flow of genetic information. Another characteristic of the acquisition of a mechanistic understanding of the flow of genetic information is the use of a broad range of biological systems from the simplest bacterial viruses to the most complex of species---Homo sapiens.

The New Human Genetics

The developments in molecular biology during the 1960s led to an increasingly detailed understanding of the multiple processes involved in DNA replication, transcription of DNA to RNA, translation of RNA to functional or structural protein products, and mechanisms for mutations of DNA that lead to altered protein products. The central dogma of molecular biology---the flow of genetic information from DNA to RNA to protein---was amended to allow for the reverse flow of information from RNA to DNA.

Reverse flow of genetic information was observed as the mechanism by which a certain class of RNA-containing viruses proliferates in an infected host cell. These viruses, or retroviruses, replicate by first making an exact double-stranded DNA copy of the single-stranded viral RNA. In most cases, the double-stranded DNA molecule is inserted into the host chromosome before producing RNA transcripts for new viral particles. This method of transmission of genetic information is especially important in any consideration of modern human genetics because of the possible role of retroviruses in cancer that results from perturbation of the normal structure and control of chromosomes. Furthermore, although perhaps not so important in the discipline of human genetics, the insidious human immunodeficiency viruses (HIV or AIDS viruses).are retroviruses. On the more positive side, nonvirulent retroviruses are being examined for potential application in gene therapy. They may serve as vehicles (or vectors) for transferring normal genes to genetically defective cells.

Following the rapid advances in molecular biology of the 1960s, a second revolution in molecular biology began in the early 1970s. This revolution, which occurred largely through the efforts of United States' scientists, provided the tools for revealing the structure of human chromosomes at the level of individual base pairs along the DNA double helix.

Starting in 1970, enzymes (called restriction endonucleases) that cut DNA molecules at specific recognition sites were discovered. These enzymes provided essential tools for constructing maps of DNA molecules. Concurrent with this discovery, improved methods were developed for high-resolution, physical separation of DNA molecules using electrophoresis in agarose gels (a chemically inert, fibrous network in which DNA fragments separate according to size because of their relative mobilities under the influence of an electric field). Within two years, enzymes that join two tailor-made (using restriction enzymes) DNA molecules were used to produce the first human-engineered, recombinant DNA molecules.

Developments in microbiology coupled with the breakthroughs in biochemistry and molecular biology provided the capabilities to propagate recombinant DNA molecules using bacterial plasmids (small, circular DNA fragments that exist and replicate independently of the bacterial genome) as vectors, or simply as carriers of the foreign DNA. During the succeeding years, numerous new restriction enzymes were isolated, new cloning vectors were developed, and these technologies became used widely to study the organization and control of genes in many organisms. In 1977 the construction of the first recombinant library from mammalian DNA led to the discovery of the unexpected complexity in the organization of mammalian genomes.

Concurrent with these scientific and technological advances, numerous national and international meetings addressed the public's concerns related to the potential hazards and applications of recombinant DNA research. In the United States, the National Institutes of Health established a set of guidelines for recombinant DNA research. With all of these developments, a new biotechnology emerged in the United States.

Advances dependent on the development of recombinant DNA technology have included, but are not limited to, the capability to determine the sequence of base pairs in DNA molecules and the capability to produce proteins in bacterial cells using recombinant DNA molecules. The first human hormone was produced in 1978 using recombinant DNA technology.

In the context of the impact of recombinant DNA technology on modern human genetics, the first example of a direct application of recombinant techniques was in the diagnosis of sickle-cell anemia, a defect in the gene coding for hemoglobin, directly at the gene level. This approach was made possible through the isolation of the human gene encoding hemoglobin. Combining this hemoglobin gene copy with the techniques for DNA isolation and restriction enzyme mapping, scientists were able to distinguish the defective hemoglobin gene from the normal gene.

These developments signalled a breakthrough not only in genetic disease diagnosis but also in applications to mapping the locations of genetic markers for all human chromosomes---the entire human genome. The major breakthroughs and the rapid advances in human genetics resulting from the combination of knowledge and technology from many different disciplines---chemistry, biochemistry, molecular biology, microbiology, physics, mathematics, computational sciences---are only the beginning of a fruitful multidisciplinary approach to deciphering the human genome. The proposed Human Genome Initiative will further stimulate progress toward understanding the organization and control of the complete set of human genes and applying this knowledge to the prevention or alleviation of genetic disease and the development of products for improving the human condition.

APPENDIX B

Biotechnology at the Los Alamos National Laboratory

As one of the world's foremost centers for multidisciplinary research, Los Alamos National Laboratory has a long history of accomplishment in pioneering the application of physical and computational methods to problems in biomedical science. Contributions began soon after the Laboratory was established in 1943 and continue today. The Laboratory has a comprehensive program in biological and biomedical sciences from which has grown an effective biotechnology component. As leaders in developing and exploiting innovative technologies to creatively address relevant social issues, Laboratory scientists have generated a unique combination of capabilities in support of experimental biotechnology. Programs in the biological and biomedical sciences are an integral part of the nation's research establishment and provide unique services to the scientific community as well as advanced training for graduate and postgraduate fellows, collaborators, and colleagues. The Laboratory's ability to assume a unique and prime role in the Human Genome Project is effectively demonstrated by the wide range of current research and technology development efforts described below. Each effort demonstrates capabilities required to address essential elements of the Human Genome Project.

To exploit the power of the world's largest scientific computing facility, Los Alamos developed a prominent program for applying computation and modeling to problems in biomedical science. Laboratory theorists are the architects and builders of GenBank, the national nucleic acid sequence data base in which all published sequences from throughout the world, together with associated biological information, are stored in computer-readable form. Los Alamos assembles the data in collaboration with the European Molecular Biology Laboratory. The National Institute of General Medical Science manages the project with funding provided by National Institutes of Health (NIH), the Department of Energy (DOE), and the National Science Foundation (NSF). In the United States, Bolt, Beranek and Newman---and secondarily many other private sector companies---distribute the data. GenBank has become a standard research tool for all those engaged in nucleic acid sequence research and is used by approximately 20,000 scientists throughout the world.

As a result of the GenBank experience, the Laboratory is providing a National Research Resource for Human Immunodeficiency Virus (HIV) Sequences as part of the U.S. AIDS program. Supported by the National Institute of Allergy and Infectious Disease, this Resource compiles, analyzes, and distributes in computer-readable form all HIV and closely related sequences. This Resource is having a major impact on the national AIDS research program. Building of virus "ancestral trees" has convinced scientists of the need for much more sequencing of HIV viruses. The information provided by the Resource is vital in assessing the very rapid rate of HIV virus mutation and has implications for the production of vaccines to protect against AIDS.

Nucleic acid sequencing generates huge amounts of data. GenBank currently has over 12 million base pairs in the data base, and new entries are accumulating at a rate of nearly 5 million base pairs per year. (Bases are the building blocks of nucleic acid.) Less than 10% of the GenBank sequences are from the human genome. Thus, only an extremely small fraction of bases in the human genome have been sequenced. Clearly, the amount of data that will have to be processed in the Human Genome Project is vast, and scientists cannot handle, much less analyze, such large quantities of data without user-friendly computer capabilities. In the absence of analysis, the potential value of sequence data is greatly diminished. Thus, Los Alamos scientists, with DOE and NIH support, are conducting research on the analysis of nucleic acid sequences. They and their colleagues have developed widely used computer methods for detecting and characterizing similarities between nucleic acid sequences. Research in the application of artificial intelligence methods has shown that "neural networks" may be useful in detecting significant functional patterns in DNA (deoxyribonucleic acid) sequences, and mathematical models have been developed to predict deviations of the DNA structure from the ideal Watson-Crick double helix. Laboratory theorists have also pioneered in developing mathematical models for diverse problems in immunology, cell biology, molecular biology, AIDS epidemiology, and neurophysiology. As a center for such theoretical modeling, Los Alamos is rivaled only by the NIH campus.

Los Alamos has traditionally been a leader in developing new physical methods for the study of biological systems. Flow cytometry, first conceived and developed at Los Alamos, has become a valued and indispensable capability in research laboratories and medical institutions throughout the world. Using laser-induced fluorescence, flow cytometry makes it possible to detect, characterize, and sort individual cells, chromosomes, and molecules as they pass through a laser beam. After 15 years of pioneering developments, the Laboratory was designated as the National Flow Cytometry Resource. Flow cytometry research and development efforts, supported by DOE and NIH, have spawned a vigorous and innovative industry within the private sector. The creative combination of flow cytometry and biotechnology established at Los Alamos and Lawrence Livermore National Laboratory will be vital to the success of the Human Genome Project.

Perhaps the most relevant example illustrating the ability of National Laboratories to cooperate and rapidly mobilize scientific expertise and technological accomplishment for a goal-oriented mission is the National Laboratory Gene Library Project. Responding to a worldwide requirement for DNA from specific human chromosomes, Los Alamos and Lawrence Livermore National Laboratories have constructed recombinant DNA libraries from individual human chromosomes sorted by flow cytometric techniques. This project is a fine example of the technological expertise that can be assembled in National Laboratories for the rapid solution of important biological problems. Not only has the Project provided a service to the worldwide scientific community, but also it has catalyzed the development of important concepts and new applications in biomedicine to which the combination of flow cytometry, molecular biology, and biotechnology may contribute. Most if not all of the information, experience, and biological materials produced serve as necessary precursors to essential program elements of the Human Genome Project. An outgrowth of the Gene Library Project is the NIH-supported Resource for Mapping DNA Probes in which, as a service to biomedical researchers, DNA fragments are mapped to specific human chromosomes. Together with GenBank, this acquired expertise provides a sound theoretical and experimental basis for associated tasks in the Human Genome Project.

There can be no doubt that new technologies must be developed to bring the Human Genome Project to a successful conclusion. Today, biotechnological methods are relatively time consuming and labor intensive. Advanced mapping and sequencing technologies are needed. Los Alamos is currently conducting feasibility studies of flow cytometry-based, single-molecule detection to develop new sequencing techniques that are much faster and less costly than methods used today. Laboratory scientists and engineers are also experienced in robotics and automation of chemical processes involving hazardous material. These skills provide a strong base for developing automated procedures for DNA sample preparation, mapping, and sequencing.

The research activities and resources described above demonstrate that Los Alamos National Laboratory has both the desire and capability to assume an integral and prominent role in the Human Genome Project. The Laboratory's strengths derive from the combination of an outstanding technical staff, computing resources second to none, and a tradition of forming interdisciplinary teams for completing applied research projects.

STATEMENT OF DR. VICTOR A. McKUSICK, UNIVERSITY PROFESSOR OF MEDICAL GENETICS, JOHNS HOPKINS CLINIC

Dr. McKusick. McKusick is the name. I am happy to be here.

I am a practicing mapper and have recently returned from the World Workshop on Human Gene Mapping.

I have been focusing particularly on the mapping of functional genes, the mapping of genes, and I think in this discussion there has not been much reference to that. There has been reference to mapping in general and a reference to sequencing, and there has been reference to how many nucleatides there are in the entire genome.

We should focus also on how many genes there are, individual genes, because this is where the action is. This is what controls everything in the human organism, and this is what goes wrong in disease. That number is something like 50,000, perhaps somewhat more than that but not more than 100,000.

How many do we now know about? That number is something that I keep tabs on in an encyclopedia of genes which is known as Mandelian Inheritance in Man, if I could make an advertisement for that. Entrepreneurial activities seem to be well favored here, so I guess that is appropriate.

There are now about 4,200 genes that we know about, which is a far cry from the 50,000. Of those, by recent count something over 1,300 have been mapped to specific chromosomes. Thirteen hundred is an impressive fraction of the 4,200 total.

The question is how are we going to find the rest of the genes, and I believe that one aspect of mapping, which is in the trade referred to CD&A mapping, express gene mapping or Exxon mapping. The mapping of express genes can be done, regardless of whether the function of those genes is known, and that, I feel, needs some concerted management to push it through to complete mapping.

This would be a great boon also to the sequencing, because I believe also that a good place to start with the sequencing effort is within the express genes and from the express genes.

I would like to say perhaps with an element of humor that there has been lots of talking about mapping/sequencing, and many of us feel the need for a word to cover this area. You cannot say mapping/sequencing. A term has been suggested, not by me although I certainly espouse the name. Genomics is the term for this field. I think the term might just catch on. It refers to gene mapping and nucleatide sequencing, the whole mix of analysis of the genome, genomics.

Again in the entrepreneurial vein, there is a new journal published by Academic Press and edited by myself and Dr. Frank Ruddle at Yale, the first issue of which is appearing this month.

Senator Domenici. What is it going to be called?

Dr. McKusick. The title is Genomics, and the subtitle is International Journal of Gene Mapping and Nucleatide Sequencing, Emphasizing Analysis of the Human and Other Complex Genomes. It is a real mouthful.

Senator Domenici. The reason I asked you to say it so many times, if you say it enough at one of these hearings, the committee might just vote that it has become the popular name, and then you will have a great victory and we will all have a much simpler job.

Let me say to all of you I think I am going to have to follow my suggestion and submit the questions in writing and ask the committee if they would like to, but with your indulgence I will ask one question of any of you who feel competent enough to answer, starting with you, Dr. McKusick, since you indicated you just returned from an international symposium on the subject.

Would you briefly answer this question? If the United States does not proceed with a goal oriented managed program to map the genome, will someone else, some other country, do it, in your opinion?

Dr. McKusick. Everyone thinks about Japan as a likely place that will go into sequencing, and I think that is very likely because of the technical activity there. I do not think they will do the mapping job. Their sequencing job will not proceed as expeditiously and as interestingly and as informatively for that reason. The mapping activity at this point, at any rate, is very low in Japan.

But to answer your question more succinctly, yes, I think that it is likely that the sequencing job will be done by Japan.

Senator Domenici. Do any of you feel sufficiently knowledgeable to answer that question?

Dr. Cantor. I would like to comment on the mapping. I was also at the same meeting in Paris last week, and I was stunned at the progress the Europeans are making in mapping. I think a number of large European groups have been able to jump into this area, physical mapping, because they have the kind of flexible funding that allows them to chart a long-range effort.

Senator Domenici. All right. Does anybody else feel comfortable answering the question?

Dr. Miller. All I can do is share with you a discussion from a writers workshop that many of us just came from at Brookhaven National Laboratory, in which the subject was discussed at length.

It was clear to me, at least, from discussions with Dr. Wata who was there from Japan, that they probably would go forth with such a project.

Dr. Mendelsohn. I agree.

Dr. Gilbert. I agree. The Japanese will go ahead with the sequencing. In order to do a sequencing project, they will have to do a mapping project.

Senator Domenici. Dr. Postma?

Dr. Postma. I agree with my panelists.

Senator Domenici. We thank you all very much, and we will be staying in touch with you. We hope we can proceed with something significant here.

Senator Domenici. Now, we need Dr. McConnell from Johnson & Johnson, Dr. Norman Anderson, LSB Corporation, and Mr. Richard Godown, Industrial Biotechnology Association.

Will the three of you please take the chair?

Dr. McConnell, we welcome you here. It would not be fair just to welcome you. We ought to thank you for the help you have been to this Senator and to this effort. The idea of the bill was the result of a day long seminar that was held here to which I asked a number of people to come. You were there. From it came two of the ideas that are in this bill, and you have from that time on, along with all your efforts, been from what I can tell diligently trying to familiarize yourself and the industry with this approach.

We very much welcome you here and look forward to your testimony. Your prepared remarks will be made a part of the record, and I would appreciate your summarizing them, please.

STATEMENT OF DR. JACK B. McCONNELL, COORDINATING DIRECTOR, ADVANCED TECHNOLOGIES, JOHNSON & JOHNSON

Dr. McConnell. Thank you very much for your kind remarks, Senator. I have only two or three comments I will make, and it will take me just one minute to do them.

First of all, there is a sense of urgency about moving forward with this. In my prepared remarks, there is a chart showing where the U.S. at one time was the dominant country in the development of new chemical entities, now that lead has slipped over to Japan.

If we allow an important scientific issue such as mapping and sequencing the genomes to slip to them as well, we would severely compromise the pharmaceutical and the bio tech industry.

I think that a consortium is the best way to go about it. It is the most effective, efficient and expeditious way, plus it will provide the controls, particularly quality controls, that are necessary to keep track of the 3 billion pieces, and I would hope that the materials that came out, there would be a right of first refusal for U.S. industries. I think that that would summarize my comments very nicely.

[The prepared statement of Dr. McConnell follows:]

TESTIMONY

BEFORE

SENATE SUBCOMMITTEE ON RESEARCH AND DEVELOPMENT

JACK B. McCONNELL

SEPTEMBER 17, 1987

Thank you for inviting me to testify before this committee and share with you some thoughts about the opportunity of mapping and sequencing the human genome.

I have been in the pharmaceutical industry for 34 years -- the first 8 years at Lederle Labs where I was on the team that worked on the development of the polio vaccine; directed the clinical research programs on several antibiotics; and was a co-inventor and the developer of the TB Tine Test. After joining Johnson & Johnson in 1961, I directed the program which led to the production and marketing of Tylenol; directed the program which led to the first commercially available Magnetic Resonance Imaging device in the United States; directed the program for the development of an artificial spinal fluid, which holds the promise of full recovery to those suffering from stroke or spinal cord injury; and developed and directed the research program to create an artificial pancreas. My present position is Corporate Director Advanced Technology, Johnson & Johnson. My statement represents my own personal views.

I agree fully with those who suggest that the genome should be mapped and sequenced. The implications for clinical medicine are staggering. It will allow us to diagnose, treat and eventually eliminate hereditary diseases.

In addition, there are economic reasons. When the two are taken together, they are sufficiently compelling to force a sense of urgency about moving forward with the task. If we want the U.S. to maintain its position as a dominant force in the pharmaceutical industry in the world, I can not imagine our letting this opportunity pass us by. Someone has said that the group or institution that first gains access to the information from mapping and sequencing the human genome will be in position to dominate the pharmaceutical and biotech industry for decades to come.

We are not the only ones in the world interested in this opportunity -- the Japanese have an active program underway designed ultimately to sequence one million bases a day. At that rate, they can complete the task in less than 10 years. The total effort in the U.S. is no where near that of the Japanese. If we proceed at our present rate, it will take us 50 years or more. By that time, we can be guaranteed of having a pharmaceutical and biotech industry which will be severely compromised.

Already one can begin to sense a slippage of the pharmaceutical industry overseas.

(3)

NEW CHEMICAL ENTITIES INTRODUCED
1982-1985 VS. 1986

	NATIONALITY OF R&D COMPANY		COUNTRY OF FIRST LAUNCH	
	'82-'85	'86	'82-'85	'86
USA	48	8	7	5
JAPAN	46	15	43	19
GERMANY	23	8	26	6
FRANCE	18	1	20	-
ITALY	17	5	26	6
U.K.	5	5	13	2
SPAIN	8	2	9	3
SWITZERLAND	14	2	13	1
NETHERLANDS	3	-	5	1
OTHER	7	4	27	7

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The U.S. pharmaceutical industry has recently dropped behind Japan in the production of new chemical entities. In the period of 1982-1985, the U.S. produced 48 new chemical entities; Japan 46. In 1986, the U.S. produced 8 and Japan 15. For those who think the Japanese are good only at applications research, this is a special reminder that that is just not true. They are also competent at discovery research. From the chart, you can see Japan is not only the country in which new drugs are first discovered, but also the one in which the drugs are first launched.

If we allow the Japanese to leap ahead of us in mapping and sequencing the genome, they will be in a good position to dominate the pharmaceutical and biotech industry. That would have a severe impact on the U.S. economy and our balance of trade.

Even though the idea of mapping and sequencing the human genome is a fairly recent one, a large body of the scientific community supports the project. Most of the discussion swirls around the process and structure by which we perform the task.

I strongly support the proposal by Senator Pete Domenici of New Mexico of a consortium of universities, private industries, and national labs, which I believe should be composed of U.S. institutions so we can get on with the task that needs to be done and to move with some expediency.

I appreciate the suggestion that there be international cooperation. That is just not practical. When one reflects on the problems we are having coming to grips with our own program while taking into account competing agenda, concerns, issues and turf problems, I fear we would hopelessly bog down the program at the outset if we tried to fold into our program other nations' concerns of similar breadth and depth of interest and intensity. Neither is it in our national interest. Our health care industry, now the strongest in the world, is at stake. There are technical spin-offs from the genome project which will have enormous economic value and I would expect each nation would prefer to use them to their own economic advantage. Additionally, I would be hesitant to see us use U.S. tax dollars to support competition and hasten the slippage of additional U.S. businesses.

A governing board of the consortium would be appointed by the secretary of DOE, in consultation with the Secretary of Health and Human Services (HHS), which would confirm the goals of the legislation, set the policies, plan and direct the program, and monitor the results.

The mapping and sequencing of the human genome should represent a new commitment by the federal government to excellence in science and technology. It should not adversely affect the funding of present research programs in biology. This is a long term commitment which requires multi-year funding to allow the consortium to plan and perform the long range tasks that will be needed for a successful program.

After the genome is mapped and sequenced, indeed, in the midst of mapping and sequencing it, the universities and private industry will be in the best position to move it forward by taking the data and translating them into information, materials and products which can be used in developing a better understanding of the disease processes and how to diagnose, treat and eliminate them.

There is no doubt that the overall work will involve several labs and institutions, certainly the N.I.H. will play a central role in formulation of the policy Other institutions that will play a significant role include Lawrence Livermore and Oak Ridge. I am pleased that the Secretary of Energy has appointed Los Alamos and Lawrence Berkeley as the lead labs for the Department of Energy.

Los Alamos National Laboratory has a track record in conceptualizing, developing, testing and prototyping large scale complex technical projects involving many organizations. Additionally, the lab has, for many years, played a leading role in pioneering the application of computers and physical methods to problems in biomedical science. As a result, Los Alamos has five NIH designated and supported National Resources including: National Flow Cytometry Resource, GenBank, Resource for Mapping

DNA Probes, National Research Resource for AIDS Sequences, and the National Stable Isotopes Resource. Be assured that no national lab has a comparable aggregation of skills nor does any private sector institution have comparable skills and only a few academic institutions can match their capabilities. Of these institutions, probably none could or would mount a program like the Human Genome Project.

Interlacing and undergirding all of this is an excitement and enthusiasm for the project at Los Alamos which is not apparent in most other agencies.

As a representative of private industry, I have visited several of the national labs. Nowhere have I found better cooperation and more eagerness to effect technology transfer than at Los Alamos. This experience will serve the consortium well by moving the data from the national labs through the universities and into private industry.

A consortium, including universities, private industry and national labs, is, in fact, the most effective and efficient way to get the job done and I will continue to work with Senator Domenici to formulate the legislation to achieve the goals. Far too long, universities, private industry and the national labs have gone their own way disregarding, possibly even disdaining, the work of the other two. It's as if they were three prospectors panning for gold in the same stream, each suspicious of the activities of the other, none wishing to give up any of their independence for a more effective and efficient process. As the scientific community is faced with opportunities of increasing importance and subtlety, it needs to move from the independence that has been a hallmark of their activities to date to a point of interdependence. The need to form partnerships is one of the strongest and most fundamental forces in nature. In the world of biology, there are no isolated creatures. Every form of life interacts with and is dependent on other forms. In planning this program, we can take a lesson from the world of biology and develop interdependent activities among the three sectors and in so doing increase the efficiency and the effectiveness of the output for the good of the commonweal.

Senator DOMENICI. Thank you very much.

Dr. Anderson.

Let me also thank you, Dr. Anderson. You have taken a lot of your time to travel long distances to attempt in very brief time intervals, so you do not judge your success based upon either your pupil or you as a teacher because we did not have much time together, but I thank you for trying to educate me on the subject, and I look forward to your testimony.

We will make the statement a part of the record and would appreciate your expeditious summarizing of this issue.

STATEMENT OF DR. NORMAN G. ANDERSON, ON BEHALF OF THE ALLIANCE FOR AGING RESEARCH

Dr. ANDERSON. Thank you very much.

In summary, I would like to say that the constituents for this bill, we believe, include the large community of aging citizens, and in my presentation I give the reasons why the project will have, we think, very dramatic effects on aging research and on aging-related diseases.

As a chairman of a small company engaged in the development of the technology for this project, we experience extraordinary frustration because it is not organized, there is no place in which to begin to express this technology, and there is no test bed, test engineering bed, in which to do the fairly large scale experiments.

We have discussed with the NIH the possibility of melding two programs. They have a requirement for sequencing AIDS virus genomes in large numbers. We have suggested that a laboratory be set up to do that continuously, which we then will use as a test bed for the development of the systems which are upstream of the sequencing itself. I think that is an extraordinarily good idea.

We are also working with the Los Alamos National Laboratory, the Oregon National Laboratory, and the Oak Ridge National Laboratory to test out how technology transfer really works in both directions.

My last point is statistically most of the new ideas, the new technology, will arise outside of the national laboratories because most people in these fields are outside the national laboratories. So it is of great concern to us how we interface with the program, especially the national laboratory.

Thank you very much.

[The prepared statement of Dr. Anderson follows:]

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*Nobel Laureate

Statement By

Norman G. Anderson, Ph. D.

On Behalf Of

THE ALLIANCE FOR AGING RESEARCH

Before The

U.S. SENATE

COMMITTEE ON ENERGY AND NATURAL RESOURCES

Subcommittee On

Energy Research and Development

Hon. Wendell H. Ford, Chairman
Hon. Pete V. Domenici, Ranking Member

September 17, 1987

Testimony of Dr. Norman G. Anderson

Mr. Chairman, I am Norman Anderson, Chairman of the Board and Chief Scientist of Large Scale Biology Corporation, a company concerned with developing new technology for the Human Genome Initiative. I was previously with the Department of Energy's Argonne National Laboratory for nine years, and spent twenty two years at DOE's Oak Ridge National Laboratory. I appear today to present the views of the Alliance for Aging Research, a non-profit advocate for science policy which was established one year ago to provide a forum for work to advance gerontology and gerontological research in the national interest. It is the goal of the Alliance to broaden the discussion of the "greying of America" to include a science strategy, including that of the Human Genome Initiative, which could lead to greater health, vitality, and potential productivity for the rapidly growing number of our elderly citizens. Over the coming one-half century there will be no more potent demographic factor in American life than the rapid increase in our population of aging citizens. The size and proportion of the group over 65 will double in the next several decades, and the number of individuals over 85 will more than quadruple by 2030. Our science policy must aim to assure that the additional years of life granted through research are years of vigorous health in mind and body. Today we glimpse clues to solving some of the disease problems of old age, which clues are written in our own genetic programs, in the DNA which is the text material for the Genome Initiative.

The Genome Initiative is designed to be part of the cutting edge of biotechnology. Biotechnology is widely regarded as the the science of the future, able in the long term to provide a large fraction of our future economic base. We have a competitive edge in biotechnology now. The core question is whether or not we maintain this competitive advantage, and reap the benefits, especially those that are health related.

Human cells are the most complex mechanisms thus far discovered in the physical universe. The basic plan for human cells is encoded in over 3 billion base pairs which constitute the DNA of the human genome. DNA contains the instructions for the working parts of cells, gene products or proteins, and a gene is a piece of DNA which codes for one protein. The long range objective of the Genome Initiative is to understand human DNA, how it is organized, what information it contains, and how that information is related to cell function and disease. The deliverables are information, research tools, software, and biological samples. They are the raw materials of genetic engineering.

Genetic engineering is concerned with identifying genes for commercially useful proteins and making those proteins in quantity. The human genome contains an estimated 100,000 genes, and human cells therefore contain approximately the same number of different proteins. Only a tiny fraction, possibly 3%, of all proteins, which are the working parts of living cells, have names or known functions. Of these known proteins, a still smaller fraction have diagnostic or therapeutic uses now. Since so few are known, nearly all genetic engineering companies work from a very limited list, including insulin, interferon, the interleukins, tissue plasminogen activator, and a dozen or more others. Every line of evidence suggests that very large numbers of clinically useful proteins remain to be discovered and exploited. The Genome Initiative is therefore basic to developments in genetic engineering.

The full Genome Initiative includes gene mapping, sequencing, and indexing. Genes are named or indexed by the proteins they make, hence indexing involves identifying the protein coded for by each gene - a difficult task but one which is now technically feasible.

Whoever carries the Genome Initiative through to near completion,, has first access to the data, and owns a large fraction of the technology will have and will probably retain world leadership in bioengineering and biotechnology and will be the first to reap the health and commercial benefits. Almost anyone can sequence small DNA fragments or make small electronic chips. World leadership goes to those who can make very large complex chips, or understand very large and complex genomes.

To merit public support, however, there must be perceived public benefits from the Genome Initiative, and it is rather simple to list, for each of the categorical institutes of the NIH, what some of those expected benefits may be. As a salient example I would like to to review very briefly the relationship of the Human Genome Initiative to aging research. Medical costs for the care of the aged, and for the treatment of age-related diseases will be an every increasing fraction of our total health care costs, and these rising costs affect each citizen.

We may ask how aging research is related to the Human Genome Initiative. Age-related diseases occur differentially in the aging population, and different individuals are differentially susceptible to osteoarthritis, osteoporosis, age-related macular degeneration, late onset diabetes, to Alzheimer's disease and to a very long list of other illnesses. The Human Genome Initiative, if carried to completion, will ultimately allow the identification of gene variants which give rise to these susceptibilities. Diagnostic tests will then become available, and new therapies based on intimate knowledge of specific disease processes can be developed and tested.

The basic aging process - inevitable aging - is also thought to have a genetic basis, and the existence of gerontogenes has been postulated. If these are genes which switch on with age, it may be possible to delay their activation. If they switch off, resulting in the loss of a gene product, then it is important to find such product(s) and determine whether they are therapeutically useful.

To date less than three percent of human gene products have names, and only a fraction of these have been carefully examined for age-related changes in man. The technology for such studies now exist, much of it developed by us. This technology will, in the foreseeable future revolutionize aging research. Research in aging and aging related diseases, which account for a very large fraction of all present and projected health costs, has thus barely begun.

Genes will ultimately be named, in the majority of instances, for the the proteins they code for. Hence to index the genome requires a systematic effort to identify all of the protein gene products, and to associate each with its gene in a large computerized data base. This work will uncover a vast array of new potentially useful diagnostic markers, and many new gene-product drugs. Such a tiny fraction of gene products are known that genetic engineering (the science of producing gene products commercially) now works from a very short list of candidates (insulin, interferon, TPA, and interleukin 2 for example). It is proposed that the HGI will radically alter this situation, and will yield an estimated 100,000 candidate gene products for exploration, most of them now unknown. The medical implication of the HGI for aging research and for biomedical research generally are therefore far reaching indeed.

Part of the technology required for the Human Genome Initiative (HGI) is described in patents pending or being filed by the Large Scale Biology Corporation. We are therefore interested in the commercial payoffs which the HGI may yield in terms of new data bases, clinically useful tests, and therapeutic reagents (including those related to aging), and in the development and use of systems, techniques, and procedures proprietary to us which are applicable to the mapping, sequencing, and indexing of the human genome itself.

With respect to bill under consideration, the problem of intellectual property rights is of great interest to us and to all interested commercial firms. We may ask whether it is envisioned that proprietary technology such as ours will be transferred to National Laboratories for development, what rights we may retain in it, and also ask how the National Policy Board on the Human Genome will make technical decisions as to whose technology to develop and adopt? It would appear essential to have access to the best and latest proprietary developments. These will arise in many different locations. If they are unknown to the planners, large sums of money may be wasted on projects which become quickly obsolete when superior proprietary developments are unveiled. It would appear that some motivation may be necessary to stimulate the sharing of intellectual property while also protecting it. These questions bear directly on the efficiency of a national effort, on whether the technology remains in the United States, and ultimately on whether we continue to maintain our world leadership in biotechnology.

Thus the Genome Initiative is a premier test case for coordinated government planning for research in the national interest, for cooperation with and stimulation of U. S. industry, for the thesis that by supporting basic and applied research with public funds our citizens benefit, and for the postulate that research support yields economic benefits which accrue in the United States.

The Alliance for Aging Research commends Senator Domenici for taking the initiative to mobilize the several Federal agencies to approach decoding the vital messages written in human DNA. The goal of this legislation -- to organize and move forward with mapping and sequencing the human genome -- clearly would be of enormous potential benefit for understanding aging and other major goals in modern medicine.

It is just as clear that a research project of this magnitude should not be undertaken as a substitute for current support for individual investigator-initiated studies that are conducted on a very much smaller scale, but which are vitally important.

If the Genome Initiative was to divert present funds for research, it could have an effect opposite from that intended, and may impede progress in cancer, cardiovascular disease, aging, and hereditary diseases. Thus any large scale diversion of Federally support could have a negative and even crippling effect on research progress in these fields.

Testimony of Dr. Norman G. Anderson

It is the understanding of the Alliance for Aging Research that it is your intent to improve the research potential of the National Laboratories and of U.S. industry to map and sequence the Human Genome and to disseminate that information to academe, industry, and to the broadest possible audience within the health field. The Alliance supports that goal and urges that as the project grows, that Federal support be increased from sources that augment rather than compete with ongoing funds for biomedical research designated for the National Institutes of Health and other federal agencies.

It was my privilege to write, in collaboration with Dr. Leigh Anderson, the original position paper for the U. S. Department of Energy proposing the Genome Initiative nearly five years ago. I request that an abbreviated version of that paper published in 1985 be included in the record at this point.

A policy and program for biotechnology

BY N.G. ANDERSON AND N.L. ANDERSON

If the biotechnology enterprise in the United States is to succeed in the long term, a unifying policy based on well-defined objectives appears necessary. And if biomedical research and biotechnology are to achieve and deserve major government and private funding comparable to that provided for aerospace, nuclear energy, and nuclear physics, the objectives must be fully comprehensible to the average person, fill a deep-felt need, and be sufficiently broad to encompass most of biology.

Man is the most complex entity in the physical universe. Although explorations of space and the atomic nucleus have achieved and deserve large-scale funding, huge facilities, strong mandates, and continued public attention, the average citizen is more interested in human mysteries: reproduction, development, birth, disease, aging, and death. This public interest and concern is reflected in the position of health care as our largest single industry.

Assuredly, the exploration of man and the cells of which he is composed will ultimately require the best minds, the most sophisticated technology, and a large and superlative organization.

Only two objectives appear to us to offer the possibility of long-term support on the scale required to maintain national leadership in biomedical research and in biotechnology: the complete sequencing of human DNA and the separation, cataloging, and characterization of all human gene products. The first objective might be called the "Plan for Man," and the second the "Parts List for Man." These objectives encompass, as necessary prerequisites and as defensible ancillary projects, much of current biomedical research and engineering and are (or can be made) readily comprehensible to nearly everyone. Both efforts are now technically feasible, both have already been organized on a small scale, and both offer means for the acquisition of new knowledge and for the solving of numerous practical problems. Progress toward reaching these objectives can be measured objectively. Overpromising need not be a problem.

DNA databases are currently organized at the European Molecular Biology Laboratory, and jointly by the firm of Bolt, Beranek, and Newman in Boston and Los Alamos National Laboratory of the U.S. Department of Energy. In both instances, reliance is largely on published sequences resulting from investigator-initiated studies, as should be the case initially. However, the Los Alamos Laboratory is now developing a human gene bank based on chromosome isolation. Hence, the chromosomal origin of each cloned DNA segment will be known. Sequencing long DNA segments on a routine basis, assembly of large numbers of sequences in order, and systematic assignment of the sequences to chromosomes will probably be beyond the interests, funding, or motivations of academic laboratories. If sequencing is fully automated (and rumors suggest industrial attempts here and abroad to do this), then the rate of data acquisition may increase by several orders of magnitude. If the automated sequencing systems are large and expensive, sequencing may need to be centralized in a few facilities. The organization and management of these facilities may be patterned after that for contemporary large accelerators.

It may also be that the major contribution of the so-called fifth generation of computers and artificial intelligence will be to elucidate in detail how human DNA is organized and how gene expression is controlled.

The new knowledge to be gained from global sequencing is breathtaking indeed. Computerized analysis of genomic architecture is already a new and exciting field in itself and will probably be the first one in biology where theory will play the key role it does in physics. The details of human development and gene regulation ultimately lie in DNA sequences. In addition, the library of genetic variants will become completely accessible as the sequences for mutant genes associated with the more than 2000 described genetic diseases become known. The key question of whether new mutations are produced in the human population by radiation or chemical mutagens will be answerable in detail. Hence, the sequencing effort is fundamental to the Environmental Protection Agency, the U.S. Department of Energy, the National Institute for Environmental Health Sciences, the National Cancer Institute, and the National Institute for General Medical Sciences, but is beyond each institution individually.

The ultimate intellectual challenge and goal of a DNA-sequencing project is to deduce man from the sequence (or show definitively that this cannot be done). Progress toward this goal would require that the mechanisms for the control and programming of gene expression be understood, that the amino acid sequence of protein gene products be systematically deduced from the corresponding DNA sequence (as can be done), that the three-dimensional structure of proteins be deducible from the sequence, that protein function be deducible from tertiary structure, that cell structure be deduced from the sum total of properties of cellular macromolecules, that human anatomical development be deduced from cellular behavior, and that genetic disease be describable purely from knowledge of sequence errors, etc. Although the challenge to deduce man from DNA sequencing will persist and be the subject of long and interesting arguments, progress toward reaching the more exotic goals listed above will be slow. However, most of them will be met, we believe, in the next or the following century. While DNA sequencing will ultimately provide much of the basic data required for a human protein database, decades are too long to wait. Hence, we currently have the absolute necessity for a parallel program to characterize human gene products (i.e., proteins).

The second major objective must be to characterize and catalog cellular proteins, the precision-made molecular machines underlying nearly all cell functions. In fact, for the near future we propose that the Human Protein Index Project[1,2] be *the* major effort, both because of the many short-term applications and because the feasibility studies for it are now almost complete.[3]

Estimates of the number of structural genes in man vary, but generally range from 30,000 to 50,000. Extracellular proteins are generally modified post-translationally, while a fraction of intracellular proteins are processed to yield two or more different forms. Therefore, any attempt to characterize and catalog human proteins systematically must deal with more than the number of structural genes. It is estimated that approximately 10% of structural genes are turned on in any one cell type; hence, if one cell type is to be analyzed, 3,000 to 5,000 proteins, plus modified proteins, must be dealt with.

Recent improvements in high-resolution, two-dimensional electrophoresis[4] give theoretical resolutions as high as 40,000 proteins, suggesting that the Human Protein Index Project is feasible.

Several ancillary techniques have been evolved that allow further study of the very small amounts of proteins separated on individual gels. Using submilligram starting samples, we can now identify groups of proteins that are coregulated, do global amino acid determinations on large numbers of proteins simultaneously, determine relatedness of wild-type proteins and genetic variants by mapping of partial digests, identify proteins immunochemically, produce antibodies to each protein, and do sufficient sequencing to enable synthesis of DNA probes so that the genes can be cloned and the proteins in question produced in quantity. In addition, nondenaturing systems are being incorporated into the mapping systems to allow histochemical methods to be used for enzyme identification. These methods require very small amounts of starting material; for example, high-resolution maps can be made using the proteins from a single frozen section.[5] In addition, new very high-resolution centrifuges are under development for precision cell fractionation to allow every protein detected to be assigned an intracellular location. Proposals for the development of such a system are now under consideration by the U.S. Department of Energy and are based, in part, on gas centrifugation technology developed for uranium enrichment.

As part of the Human Protein Index Project, a library of both monoclonal and polyvalent antibodies will be required so that the distribution of each protein in cells and tissues may be confirmed and so that clinical tests for the proteins that vary in disease can be rapidly developed. Parallel programs to develop comparable, identified protein data bases for mice, rats, corn, and wheat (among others) will ultimately be required. Comparative studies will also be needed to attempt to resolve many interesting problems in both human and animal evolution. It is, in fact, difficult to imagine very much research in biochemistry, molecular biology, genetics, medicine, or in many areas of zoology that will not ultimately contribute to the two main objectives suggested here.

Large national efforts do not generally arise by consensus of the scientists and technologists concerned. Neither the space nor nuclear energy programs in their present forms would have been approved by the scientists ultimately involved, if that vote had been taken before the programs were originally established. Hence, the fundamental decision to establish a DNA sequencing or a Human Protein Index effort is an almost purely political one. C.P. Snow pointed out that, in the past, most decisions in science and technology were made in secret, unknown to the majority of those ultimately affected. (He also pointed out that in government, scientists should be "on tap but not on top".) Secrecy relative to very major decisions such as those suggested here was never desirable and is no longer possible. If, as George Keyworth (Director, Office of Science and Technology, The White House) has suggested, biotechnology is the most important high technology for the future of the United States, and if (as nearly all major countries have concluded) future economic progress depends on mastery in high technology, then it is essential that the ideas described here have the widest possible discussion.

The transition in physics from small-scale efforts to large-scale problem solving occurred under wartime pressure, while the parallel transition in space exploration was largely driven by Sputnik and defense requirements. A similar transition and redirection may now be required if the United States is to win the so-called biotechnology race. Whether this transition can be made for nonmilitary, humanitarian, and economic reasons provides an interesting test of our civilization.

The policy we propose is to organize biomedical and biotechnological research around two major, understandable, and technically feasible very long-range goals, which can logically encompass nearly all present program objectives and which can also support the engineering and development now required to master biology and biotechnology. Few existing genetic engineering and biotechnology companies will fail to see at once where they might fit in.

To be realistic, a national biotechnology program must be planned for at least a twenty-year period, with major milestones spelled out for the first eight years. The average length of time between innovation (either administrative or scientific) and success or failure in achieving an end result or use appears to be at least five years.

An eight-year span, therefore, would give three years for start up and time for at least one innovation-application cycle.

The best guides to the organization and philosophy of sizable multidisciplinary efforts remain the books by Webb, who organized NASA,[6] and Weinberg,[7] who supervised the maturation of the Oak Ridge National Laboratory under the Atomic Energy Commission.

Success or failure will *not* be solely dependent on our own efforts; we have competition. A day of judgment lies ahead. There is the very real possibility that, within a decade, biomedical scientists and technologists in the U.S. may join their fellows in the electronics and automotive industries as spectators. Then neither policy nor programs will help. The U.S. biotechnology die is being cast now.

References

1. ANDERSON, N.G. and ANDERSON, N.L., "Molecular anatomy," *Behring Inst. Mitt. 63*, 169–210 (1979).
2. ANDERSON, N.G. and ANDERSON, N.L., "The human protein index," *Clin. Chem. 28*, 739–748 (1982).
3. ANDERSON, N.G., and ANDERSON, N.L., "The human protein index project and the molecular pathology data base," *Medical Laboratory 11*, 75–94 (1982).
4. ANDERSON, N.L., NANCE, S.L., PEARSON, T.W., and ANDERSON, N.G., "Specific antiserum staining of two-dimensional electrophoretic patterns of human plasma proteins immobilized on nitrocellulose," *Electrophoresis 3*, 135–142 (1982).
5. GIOMETTI, C.S. and ANDERSON, N.G., "Muscle protein analysis, III: Analysis of frozen tissue sections using two-dimensional electrophoresis," *Clin. Chem. 27*, 1918–1921 (1981).
6. WEBB, JAMES E., *Space Age Management: The Large-Scale Approach* (McGraw Hill, New York, 1969).
7. WEINBERG, A., *Reflections on Big Science* (MIT Press, Cambridge, Mass., 1967).

Senator DOMENICI. Thank you very much.

Dr. Godown, you are from right around here, are you not?

Dr. GODOWN. Yes, sir.

Senator DOMENICI. So if we need you back, it will not be a long trip.

Dr. GODOWN. I will be glad to accommodate. Thank you very much.

Senator DOMENICI. Your prepared remarks will be made part of the record. Would you please summarize for us?

STATEMENT OF DR. RICHARD D. GODOWN, PRESIDENT, INDUSTRIAL BIOTECHNOLOGY ASSOCIATION

Dr. GODOWN. I can get on and off in one minute with seven declarative sentences.

The genome should be mapped before sequenced except for sequencing sights that have been associated with diseases.

We feel that NIH, NSF and DOE should all participate both in formulating the genome initiative and performing the research, but that NIH should be the lead agency.

We believe that genome mapping and sequencing work should be carried out primarily in university laboratories and national laboratories.

We believe a human genome policy board should be composed of approximately 50 percent university representatives, 30 percent government representatives and 20 percent industry representatives.

We believe the national human genome research project should be done cooperatively with other countries if possible if this will not result in delays.

We support a human genome initiative only if funds from other areas of biomedical research are not reduced as a result, and we believe that all of the funds for a human genome project should be supplied by the Federal Government.

The "we" in each case is the Industrial Biotechnology Association.

[The prepared statement of Dr. Godown follows:]

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TESTIMONY

OF

RICHARD D. GODOWN,

PRESIDENT,

INDUSTRIAL BIOTECHNOLOGY ASSOCIATION

ON S. 1480

BEFORE THE

SUBCOMMITTEE ON ENERGY RESEARCH & DEVELOPMENT

OF THE

SENATE ENERGY AND NATURAL RESOURCES COMMITTEE

SEPTEMBER 17, 1987

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Mr. Chairman and members of the subcommittee:

My name is Richard D. Godown. I am appearing before you today as the president of the Industrial Biotechnology Association (IBA), a trade association of 64 companies that are using biotechnology to produce new healthcare, agricultural, and consumer products.

I would like to begin my testimony on Title II of S. 1480 by commending the chairman and Senator Domenici for their recognition of the importance of establishing a coordinated program to map the human genome. I should add that the question of mapping and or sequencing the human genome has engendered considerable debate within the scientific community and within IBA's membership as well.

Based on the results of a survey of our members, IBA endorses the concept of a human genome initiative, as proposed in S. 1480, with the following modifications:

- o The genome should be mapped before it is sequenced, except for sequencing sites that have been associated with disease. There are two reasons. First, there is a greater consensus on the scientific value of a genome map plus partial sequence than on a genome map plus complete sequence. Second, sequencing is now done largely by hand and is very expensive ($1 per base, with

6,000,000,000 bases estimated to be sequenced). New automated sequencing technologies are now being developed that would lower the cost to 1¢ per base.

- NIH, NSF, and DOE should all participate in both formulating the genome initiative and performing the research, but NIH should be the lead agency for both program formulation and execution. (S. 1480 proposes that DOE be the lead agency).

- The genome mapping and sequencing work should be carried out primarily in university laboratories and national laboratories. Only a minority of those who support a genome initiative believe that a government/industry/university consortium or a new center created for this purpose would be appropriate. (S. 1480 proposes creation of a consortium).

- A Human Genome Policy Board should be composed of approximately 50% university representatives, 30% government representatives, and 20% industry representatives. (S. 1480 proposes a Board dominated by federal personnel.)

- A national human genome research project should be done cooperatively with other countries if this will not result in delays. (S. 1480 proposes excluding foreign cooperation.)

- IBA supports a human genome initiative only if funds for other areas of biomedical research are not reduced as a result.
- All of the funds for a human genome project should be supplied by the federal government.

These issues are discussed in greater detain below.

Reasons to Map and Sequence the Human Genome

There are a variety of reasons for seeking additional knowledge about the makeup of the human genome.

First, knowing the entire human genomic sequence will allow scientists to more rapidly identify the genes involved in human genetic diseases. More than 3,000 human genetic diseases have been defined, but very few of the disease genes have been specifically identified.

Second, mapping and sequencing the genome will enable us to better understand the genetic differences between individuals. Human beings differ from one another by approximately 1/10 of 1 percent of their nucleotides. These differences make virtually every human being distinct from every other human being, except for identical twins. These differences may have substantial medical implications when they are associated with systems that play important roles in protecting humans against disease. Particular differences in the genes of this system appear related with such autoimmune-related diseases as diabetes and multiple sclerosis.

Third, mapping and sequencing the human genome may also help us understand cancer cells better. Cancer cells differ from normal cells because they reproduce in an uncontrolled manner. One of the keys to understanding cancer is to determine the reasons underlying this difference. Studying the genome may enable us to determine how certain proteins function to cause cancer.

Fourth, sequencing the genome could enable us to compare similar DNA sequences from humans and other animals to provide insight into evolutionary mechanisms.

Finally, it is possible that in the next ten to twenty years, sufficient data will become available to allow the three dimensional shape of proteins to be predicted from their amino acid sequence. The ability to predict protein structure from the amino acid sequence will in time enable us to engineer proteins for therapeutic purposes more quickly, accurately, and functionally to treat human disease states.[1]

While it is clear that sequencing the genome is likely to lead to significant benefits, however, some concerns have arisen as well. Many biologists believe that sequencing the entire human genome, as opposed to those genes which have been linked with disease states, may be wasteful and trivial, because as much as 95% of the DNA contained in the genome may be non-functional. Unless low cost automation of sequencing procedures is available, it may be unreasonably costly to sequence the entire human genome rather than just those portions of the genome identified as important.

The success of sequencing the genome therefore depends heavily on advances in the relevant technologies. IBA proposes that the physical mapping of the human genome, which should be feasable within the next five years or so and is considered a worthwhile endeavour by most biologists, be the first focus of the human genome initiative, with sequencing done primarily for sites associated with diseases until automated sequencing technology is developed to reduce the cost.

Federal Agency Involvement

IBA members who support a genome initiative believe that three federal agencies should play a substantial role in formulating and executing the genome initiative. These are the National Institutes of Health, the National Science Foundation, and the Department of Energy. Our members strongly believe that NIH should act as the lead agency for both program formulation and performance; in fact, three times as many said that NIH should run the show as said DOE should lead.

This is hardly surprising, given the preeminent role that NIH has played in funding biomedical research of all kinds. IBA believes that NIH possesses greater expertise and experience in genomic research than any other agency. NSF would offer the greatest expertise in the development of instrumentation and, in addition, is experienced in mapping nonhuman genomes. DOE should be included because it has conducted some mapping research already and is the agency that possesses the greatest sense of purpose with respect to a major new genome program.

I should note, however, that virtually all of the IBA members who support a human genome initiative would withdraw their support if funds were only available by reducing funding for other areas of biomedical research.

Laboratories Performing the Research

IBA believes that the genome research should be carried out in university laboratories and national laboratories, such as the Department of Energy's national laboratories and the National

Institutes of Health intramural research program. IBA opposes creating a new center or consortium for this purpose.

Constituency of a Human Genome Policy Board

IBA would like to suggest that a Human Genome Policy Board be created which contains greater university and industry representation than is proposed in S. 1480. We propose that a Board be composed of 50% university representatives, 30% government representatives, and 20% industry representatives. The government representatives would be appointed by NIH, NSF, and DOE. The university representatives should be appointed by the government agencies, with NIH appointing a majority.NIH should also appoint both industry representatives. We believe that a policy board thus constituted would be appropriately skewed towards university rather than government representation, and towards biomedical and health researchers rather than engineers.

Cooperation with Other Countries

IBA believes that a national genome project should be done cooperatively with other countries if possible, but only if such cooperation does not interfere with our efforts to initiate and accomplish our project goal in a timely manner, and additionally, only if such a cooperative effort is truely two-way so that all rights are protected, and the project efforts are enhanced.

Funding

IBA believes that all funding for a human genome project should be provided by government. We believe that this project is the sort of basic research that will need substantial further research and development to produce useful therapeutic products. We anticipate that the industry will be funding most of those additional efforts.

Mr. Chairman, thank you for this opportunity to present the views of our industry.

[1] Smith, L. and Hood, L., "Mapping and Sequencing the Human Genome: How to Proceed," Bio/Technology 5, 933-939 (1987).

Senator **Domenici**. Thank you very much. Since you are all in some way or another associated with some private sector activities, I assume you are, too, are you not, Doctor?

Dr. **Godown**. Yes, sir.

Senator **Domenici**. Let me tell you the one thing that has come across in this hearing that is slightly inconsistent with what I had been thinking about and the direction I was moving in in the bill.

With reference to mapping and sequencing, to the extent that the government involves itself in management and the development of the technology for doing it and the actual mapping and/or sequencing, it seems that while it is absolutely imperative for the private sector to have this in order to remain up front in the world in terms of wellness, disease control and biomedicine, it seems that what we are really talking about is perhaps a generic base of information that would evolve.

I am having a little difficulty in my own mind now with the idea of how does business fit into the early stage, the stage we are speaking of, other than making sure it is done right and that it is done in a way that is usable.

I guess what I am saying is, it will almost become universal knowledge in any event, it seems that people are saying, so why would the private sector contribute up front if that is the case.

Dr. Anderson.

Dr. **Anderson**. I think that would distinguish two things: the data that is gotten, which is the data base, and all of the technology necessary to get it, the hardware.

I think one thing that has not been made clear so far is that the essence of this project is an engineering project, and that is why DOE is interested in it. There is a lot of applied work. There is a lot of innovation, invention, et cetera. We and others, and I can speak for all the companies that I am associated with, are extraordinarily interested in developing the hardware, owning the patents to these concepts and ideas, and making them available to the project.

Senator **Domenici**. Dr. McConnell.

Dr. **McConnell**. The data base, you are quite right. It would probably end up being generic, but private industry would like to have an active and very important and an upfront part to play in the formulation of the policy and having a front row seat and, if possible, to get right of first refusal to the data as they come out.

The materials that will be developed, the technology we will develop, the instrumentation, will probably be patentable, in which instance we would like to have the right to get access to those patents and to market it, just as Dr. Anderson said.

Senator **Domenici**. Dr. Godown.

Dr. **Godown**. We think that private industry could help by being members of the policy board in supplying direction at that stage.

Also, we are talking about basic research, and I agree with the other two gentlemen. Private funding will certainly come in as you take this basic research beyond into applied research, the more research and development that are necessary in order to come about with the practical applications.

Senator **Domenici**. In expressing my state of mind, I understood that part rather easily, how that would occur. It was from now through mapping to whatever stage of sequencing, it appears to me that that knowledge is going to have to be available on a very broad base if the government pays for it, but I understand better what you are talking about in terms of somebody will supply technology for its utility and for its evolution and to make the next stage more useful as described by Mr. Godown.

It is in that context that you are speaking, Dr. Anderson and Dr. McConnell, if I understand you correctly.

Dr. **McConnell.** That is correct.

Senator **Domenici.** I am sure we have many more questions, and several members of the committee indicated they are going to have some for the record. They will be submitted to you and the other panel members. We would appreciate as prompt a reply as you can, perhaps ten days. That would help us in terms of our time schedule here.

We are most appreciative of your participation.

I would say, Mr. Godown, with reference to who should be the lead agency, I think we are going to be able to work that out. We are really not talking about a turf battle. We are trying to determine what the laboratories of the country should do.

Clearly, you indicate in your statement that they ought to have a major role in doing the technology of mapping and sequencing, but you express the notion that NIH ought to be in charge of the direction in which everything goes, if I am reading you right.

Dr. **Godown.** You are, Senator.

We took a poll of our membership, by the way, which I would be glad to enter for the record if it would be useful to the committee, and it was a very strong feeling on the part of our members that NIH should lead the effort.

Senator **Domenici.** I thank you very much. This committee will be adjourned until the call of the Chair. Thank you very much.

[Whereupon, at 4:30 p.m., the hearing was adjourned, subject to the call of the Chair.]

[Subsequent to the hearing the subcommittee received the following:]

SAM NUNN, GEORGIA, CHAIRMAN

JOHN C. STENNIS, MISSISSIPPI
J. JAMES EXON, NEBRASKA
CARL LEVIN, MICHIGAN
EDWARD M. KENNEDY, MASSACHUSETTS
JEFF BINGAMAN, NEW MEXICO
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TIMOTHY E. WIRTH, COLORADO
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JOHN W. WARNER, VIRGINIA
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ARNOLD L. PUNARO, STAFF DIRECTOR
CARL M. SMITH, STAFF DIRECTOR FOR THE MINORITY

United States Senate
COMMITTEE ON ARMED SERVICES
WASHINGTON, DC 20510-6050

December 2, 1987

Honorable Pete V. Domenici
United States Senate
Washington, D.C.

Dear Pete:

Thank you for your letter of November 18, 1987 in which you request a copy of the transcript from the November 7, 1987 Defense Industry and Technology Subcommittee hearing on National Laboratories.

In response to your request, a copy of this transcript has been provided under separate cover to Teri Curtain with the Subcommittee on Energy Research and Development of the Senate Committee on Energy and Natural Resources.

I was happy to have been of assistance to you in this matter.

Sincerely,

Sam Nunn
Chairman

(Committee Note.--Hearing entitled "Department of Energy's Nuclear Weapons Laboratories" (S. Hrg. 100-506) is available from the Senate Armed Services Committee.

Comments of

David T. Kingsbury
Assistant Director for
Biological, Behavioral, and Social Sciences
National Science Foundation

for the

Subcommittee on Energy Research and Development
of the
Senate Committee on Energy and Natural Resources

TITLE II OF S.1480
MAPPING THE HUMAN GENOME

Over the past two years there has been considerable discussion of the merits of mapping and sequencing the human genome. The current discussion began in response to the plans for a sequencing project outlined by the Office of Health and Environmental Research (OHER) of the Department of Energy. As originally described, the "human genome project" was limited to the development of technology and the determination of the actual nucleotide sequence of the human genome. As discussion of the project expanded the scope and focus of the undertaking also began to change. The current concept of the human genome project is vastly broader and more complex than the simple sequence determination. As S.1480 so well points out, there are many compelling reasons for obtaining the information about the nature of the human genome. As described in Section 201(a)(2) and (3) the implications for human health and economic competitiveness are substantial. However, it must be immediately recognized that the inclusion of the applications of the mapping and sequencing information moves this project substantially outside of the original concept as developed by the Department of Energy and immediately broadens the context under which it must be viewed.

To be maximally useful the sequencing data must be developed together with accurate physical and genetic mapping. These data are being generated by many researchers working on a variety of human genetic diseases. Human genetic diseases serve as the "genetic markers" or heritable traits which are necessary for the development of the genetic map. The identification of an affected gene and its function is critical to the eventual application of the DNA sequence information. Likewise, comparative biology to other mammalian species in which extensive genetic mapping has been possible is essential to the identification of those genes not recognized as inborn genetic errors in humans. Physiologically active materials like growth factors and immunomodulators have generally been recognized through animal experimentation. This work is not generally supported by the Department of Energy and in this broad interpretation of the "Human Genome Project" falls well outside of the Department's programs. For this reason careful interagency coordination between all of the affected agencies is essential. This coordination, however, should not be designed to establish a single lead agency but instead to foster open interaction on an equal footing.

Over the past few months a coordination group has been meeting and has proven the value of broad scale coordination. This group has been a subcommittee of the Domestic Policy Council

Working Group on Biotechnology and includes NIH, NSF, DOE, FDA and USDA. The EPA is also considering participation. The group has been very effective in developing understanding of the various agency programs and in identifying areas of similarity and areas of uniqueness. It is very clear that the agencies' programs form a continuum which no single agency could support alone but within which there are many feed-back loops.

The experience gained over the past few months has clearly demonstrated that interagency coordination is best achieved by a committee representing all of the agencies. In this context the "National Policy Board on the Human Genome" to be established within the Department of Energy as proposed in Sec. 202, places control and responsibility for this coordination under a single agency which does not span the entire range of relevant activities.

The subject of this legislation is most realistically the focused, coordinated effort within the Department of Energy on the development of new technology for sequencing DNA and the determination of the sequence of the human genome. This accounts for the major portion of the DOE activity and it is an integral part of the total program of research related to the human genome. A management plan for that portion of the project fall well within the oversight of the Secretary of Energy. However, the full human genome project is a much larger enterprise and this fact should be recognized during the final development of any such legislation.

WHITEHEAD INSTITUTE

Dr. David Baltimore
Director
617/258-5155

John Pratt
Associate Director
617/258-5104

September 16, 1987

Terry Curtin
US Senate
Cmt. on Energy and Natural
  Resources
Washington, DC 20510

Dear Ms. Curtin:

Enclosed please find an article written by David Baltimore on sequencing the human genome. Most of his views are expressed in this article and should be of help for the September 17th meeting.

Sincerely,

Denise Lintner

Denise Lintner
Administrative Assistant

Encl.

Whitehead Institute for Biomedical Research / Nine Cambridge Center, Cambridge, MA 02142 617/258-5000

GENOME SEQUENCING: A Small-Science Approach

David Baltimore

David Baltimore is director of the Whitehead Institute for Biomedical Research and professor of biology at the Massachusetts Institute of Technology. He received his B.A. from Swarthmore College in 1960 and his Ph.D. in biology from Rockefeller University in 1964. Before being named director of the Whitehead Institute, he was with MIT's Center for Cancer Research. Baltimore was awarded the Nobel Prize in Physiology or Medicine in 1975 for the discovery of reverse transcriptase and related work on retroviruses.

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GENOME SEQUENCING: A Small-Science Approach

David Baltimore

Debate has intensified over the past few months about whether to organize a frontal assault on the structure of the human genome. At first glance it might seem that the answer is, "Of course we should." After all, the tools are either available or under development, and the goal is hard to fault. In thinking about the question, however, I find it much more complicated than it might first appear. It involves both political calculations—because an all-out research program invites political and bureaucratic interference—and scientific compromises.

Before considering some of the negative aspects of the proposal, I must start by saying that if we knew the complete nucleotide sequence of the human genome, it would be an important reference source for all people working in mammalian biology. But to derive the information will require many person-years of effort, much money, and a large organizational structure. Thus, it seems to me that we have to consider some quantitative questions in relation to the proposed program. For example, how high a priority should such a program have? How much of our ongoing scientific activities are we willing to give up to achieve this end?

In other words, is the lack of a human genome sequence a serious limiting factor in today's biology? Phrased this way, the question is easier to answer. For most research activities of which I am aware, the lack of a genome sequence is not a limiting factor. The sequence might be useful—as are many things—but it is not crucial.

This answer is important in evaluating the proposal because we have a long-established method of scientific decisionmaking in the United States: the peer review system. This system asks about priorities and sets priorities. If a National Institutes of Health (NIH) study section were to consider a program involving the expenditure of, say, $50 million a year to sequence the human genome, the proposal would probably be considered fundable but would be given a relatively low priority. On the NIH scale of 1 to 5, with 5 being the lowest, it would be rated somewhere around 2.5. This score must be viewed against a background of fine proposals that today receive marks as high as 1.7 and are not being funded, and even superb proposals, rated at 1.5 or better, that have a hard and unpredictable course.

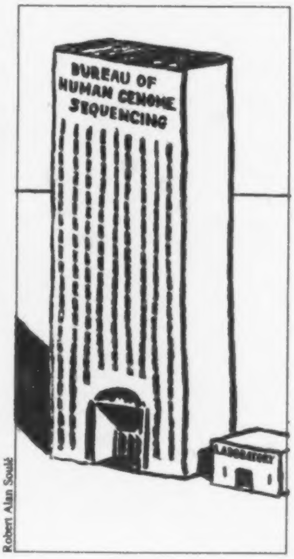
In my view, if there is any federal agency or private organization that is willing to put up money to move modern biology forward more rapidly, it should set up and use a peer review system for evaluating investigator-initiated proposals. The program could certainly have a goal: one relevant to this discussion might be to learn more about the structure of the mammalian genome. It could solicit proposals, and many proposals would certainly come in. Again, second-guessing the peer review system, I suspect that inventive proposals for making a map of landmarks along the genome would do very well and that proposals for sequencing specific genes or well-defined regions of the chromosomes would do well. However, proposals for sequencing the noncoding regions of genes or for determining the sequence of random pieces of DNA would do well only if they were set up as experiments. For instance, many scientists believe that random sequencing will only turn up nonsense, whereas others believe that there are golden opportunities for understanding buried away in the apparently uninteresting regions between genes and within introns. Given serious scientific uncertainty, a proposal to take 100 random clones and sequence them, or to take a small chromosome fragment and sequence it completely, might get a very high priority. Once that experiment was done, we would have a better idea whether random sequencing would likely be profitable or unprofitable.

I am proposing that this endeavor be undertaken as "ordinary science," not as some type of organized megaproject. I am explicitly arguing against certain models that have been suggested for the sequence project, including a centralized laboratory for mapping and sequencing and a federally directed program for mapping and sequencing, as Walter Gilbert suggests (p. 26). Some, like Gilbert, will argue that there are important benefits to centralized data collection and analysis, both benefits of scale and benefits of an organizational nature. I agree that a program that will accumulate so much raw data needs a central repository and that a proposal to establish one should receive a sympathetic hearing. NIH has already funded such a program in GenBank, the nation's DNA data base located at Los Alamos National Laboratory. In fact, I would hope that proposals to increase the effectiveness of GenBank would be an early result of a targeted program to understand the human genome.

There are other issues to consider when thinking about megaprojects and biology. First, the belief that new money is going to appear for a sequencing effort and that this project will not compete with other priorities is naive. It is appropriate that priorities compete, and the political process will certainly ensure that funds in the Department of Energy, the National Institutes of Health, and elsewhere are all considered part of the total available for biomedical research. The Office of Management and Budget routinely tracks research support. A huge, low-priority project in biology would undercut the efforts of those who argue that very high priority science is not being funded today.

Second, megaprojects are inviting targets for the political control of science. The ordinary science we do is "small science" and, because of the small packages of money that go into small science, it is not a target for direct political control of projects. A senator is unlikely to fight for a $100,000 grant to be awarded in his state but will certainly fight for a $50 million project. Thus, a megaproject like sequencing the human genome is certain to increase the political control over scientific decisionmaking.

Finally, we must realize that a megaproject invites bureaucratic control of science. In the small-science mode, the investigator and his contacts at funding agencies are able to work together with mutual respect and understanding. Yet, as became evident during the war on cancer of the 1970s, when large amounts of money are at stake, the control from Washington


BUREAU OF HUMAN GENOME SEQUENCING
LABORATORY

Robert Alan Soulé

becomes stronger. I believe that in the funding of science, contracts should be used sparingly, investigator-initiated grants should be the rule, and there should be no czars.

To summarize, the peer review system may not be perfect but, in close analogy to the democratic process, it is the best system we know. In all questions of scientific funding, peer review should be the primary mode of decisionmaking. If we remember that principle, we will not go wrong. ■

APPENDIX

RESPONSES TO ADDITIONAL COMMITTEE QUESTIONS

Follow up Questions for Hearing on S. 1480

September 15 and 17, 1987

From Senator Wendell Ford

Department of Energy

1. What percent of the Department's research is conducted in our National Laboratories?

2. For the record, please provide a list of the nine national laboratories referred to in S. 1480.

3. Please explain, for the record, the definition of a national laboratory and a federally run laboratory--how does the Department differentiate between the two? Are there other classifications of Laboratories? If so, please elaborate. Under S. 1480, as amended, would DOE laboratories--other than the national laboratories--benefit in any way?

4. Please provide a list of all DOE national laboratories that currently conduct research on:

- the human genome;
- semiconductors;
- superconductors; and,
- entrepreneurial studies.

5. Please provide a list of all DOE national laboratories that are involved in the transfer of technology.

6. Please provide the same information requested in questions 4 and 5 for the DOE federally-run laboratories.

7. How would technology transfer regulations differ for Titles I, II, and III in S. 1480?

8. If S. 1480 (as amended) were passed, what significant changes would occur in current DOE technology transfer regulations?

9. How would these changes affect the flow of information from the laboratories?

10. Provide for the record the Department's technology transfer activities directed at encouraging:

- industrial participation?
- academic community participation?
- scientific community participation?

10a. Do you believe the technology transfer program in the Department is run in the most effective manner? What changes could be brought about to make it run more efficiently? How do your regulations differ from those in the Department of Commerce?

10b. Please list the steps taken by the Department once a request is submitted by a national laboratory to initiate a licensing agreement between that lab and a private company. Also, indicate, after each step, an estimated and realistic timeframe required to complete this step.

Superconductivity

11. In light of the rapid advances into superconducting materials, how does the Department intend to take advantage of these discoveries? How will these and future discoveries be integrated into the Department's basic research and development efforts?

12. Do you intend to work with the Electric Power Research Institute (EPRI) in carrying R&D on electric power applications of superconductivity? How will this take place?

13. To what extent should the U.S. participate or encourage international collaboration in R&D and commercialization?

Human Genome

14. Please explain how the Department of Energy got involved in research on mapping the human genome. I understand that it stems from your research into illnesses resulting from energy-technology--such as radiation effects--and the Department's work in nuclear medicine. But how and when did the Department's directive turn to more extensive medical-related issues, such as the GenBank and the National Lab Gene Library?

15. In your written testimony, you mention a certain number of known genetic diseases--3000. How many of these illesses are known to be brought on by exposure to, or somehow relating to, energy-technologies?

16. What concerns, if any, have been expressed regarding possible controversial and ethical implications of mapping the genome? How has the Department dealt with these concerns?

QUESTIONS FROM SENATOR FORD
HEARING ON S. 1480, September 15 and 17, 1987

1. What percent of the Department's research is conducted in our national laboratories?

Approximately 51% of the Department's research dollars is expended at our multi-program national laboratories. In addition to the national laboratories, the Department conducts research activities at Energy Technology Centers, and single program laboratories such as Fermi and the Princeton Plasma Physics Laboratories, and contracts for research performed by the private sector and academia at the contractors' own facilities.

Q.2. For the record, please provide a list of the nine laboratories referred to in S. 1480.

A. Argonne National Laboratory
Brookhaven National Laboratory
Idaho National Engineering Laboratory
Los Alamos National Laboratory
Lawrence Berkeley Laboratory
Lawrence Livermore National Laboratory
Oak Ridge National Laboratory
Pacific Northwest Laboratory
Sandia National Laboratories

Q.3. Please explain, for the record, the definition of a national laboratory and a federally run laboratory--how does the Department differentiate between the two? Are there other classifications of laboratories? If so, please elaborate. Under S. 1480, as amended, would DOE laboratories--other than the national laboratories--benefit in any way?

A. National laboratories is a term that is generally used to describe the nine major multiprogram laboratories of the Department of Energy listed in the preceding answer. Federally run laboratories refer to facilities which are operated by Government employees. The Department's primary federally run laboratories are Morgantown Energy Technology Center and Pittsburgh Energy Technology Center which are under the Fossil Energy program.

The Department differentiates between the two by referring to the federally run laboratories as Government-owned and Government-operated (GOGO) facilities and to national multiprogram laboratories as Government-owned, contractor-operated (GOCO) facilities. The GOCO laboratories are owned and funded by the Government and operated by private industry, university, or a consortia of universities. In general, they support two or more programs and are large multidisciplinary facilities with broad capabilities in physical and life sciences, and engineering.

The Department also uses another classification of laboratories which is the single-program or program-dedicated facility. These laboratories perform research primarily for a single program. DOE has about 30 of these facilities, and most of them are GOCO's.

S. 1480 would impact some of these single-program laboratories since, for example, some of these facilities have superconductivity expertise. The Departmental laboratories are, in effect, an integrated system which utilizes the best resources available in the system. The weakening of overall governmental oversight would be a disbenefit to the primary technical mission, just as it would for the national laboratories.

Q.4. Please provide a list of all DOE national laboratories that currently conduct research on:

- the human genome;
- semiconductors;
- superconductors; and
- entrepreneurial studies.

A. The following are the DOE national laboratories conducting research in the specific areas mentioned:

The Human Genome

Los Alamos National Laboratory

Lawrence Livermore National Laboratory

Oak Ridge National Laboratory

Pacific Northwest Laboratory

Lawrence Berkeley Laboratory

Brookhaven National Laboratory

Semiconductors

Sandia National Laboratories

Lawrence Livermore National Laboratory

Argonne National Laboratory

Los Alamos National Laboratory

Lawrence Berkeley Laboratory

Oak Ridge National Laboratory

Brookhaven National Laboratory

In addition to these national laboratories, semiconductor research is also being conducted in the following Departmental single-purpose laboratories:

Solar Energy Research Institute

Ames Laboratory

Stanford Synchrotron Radiation Laboratory

Superconductors

Argonne National Laboratory

Brookhaven National Laboratory

Oak Ridge National Laboratory

Los Alamos National Laboratory

Lawrence Berkeley Laboratory

Sandia National Laboratories

Lawrence Livermore National Laboratory

Pacific Northwest Laboratory

In addition, superconductor research is conducted at the following single-purpose laboratory:

Ames Laboratory

Entrepreneurial Studies

To our knowledge, the Department does not fund any entrepreneurial studies.

Q.5. Please provide a list of all DOE national laboratories that are involved in the transfer of technology.

A. Multiprogram Laboratories

Argonne National Laboratory
Brookhaven National Laboratory
Idaho National Engineering Laboratory
Los Alamos National Laboratory
Lawrence Berkeley Laboratory
Lawrence Livermore National Laboratory
Oak Ridge National Laboratory
Pacific Northwest Laboratory
Sandia National Laboratories

Single-Program Facilities

Ames Laboratory
Bettis Atomic Power Laboratory
Energy Technology Engineering Center
Fermi National Accelerator Center
Knolls Atomic Power Laboratory
Morgantown Energy Technology Center
Pittsburgh Energy Technology Center
Princeton Plasma Physics Laboratory
Solar Energy Research Institute
Stanford Linear Accelerator Center
Savannah River Laboratory
Bates Linear Accelerator Facility
Center for Energy and Environment Research
Environmental Measurements Laboratory
Inhalation Toxicology Research Institute
Laboratory for Energy Related Health Research
Laboratory for Radiobiology and Environmental Health
Michigan State University-DOE Plant Research Laboratory
New Brunswick Laboratory
Notre Dame Radiation Laboratory
Oak Ridge Associated Universities
Radiobiology Laboratory (University of Utah)
Savannah River Ecology Laboratory

Q.6. Please provide the same information requested in questions 4 and 5 for the DOE federally-run laboratories.

A. With regard to Question 4, no research in these four areas is being done at federally-run laboratories. With regard to Question 5, Pittsburgh Energy Technology Center and Morgantown Energy Technology Center are involved in technology transfer.

7. How would technology transfer regulations differ for Titles I, II, and III, in S.1480?

Since the technology transfer provisions of Titles I, II, and III of S.1480, as amended, are substantially identical, technology transfer regulations implementing Titles I, II, and III of S.1480 would also appear to be substantially identical. However, in section 3152 of the Department of Defense Authorization bill regarding the Department of Energy Semiconductor Technology Research Excellence Initiative, it is provided that technology transfer procedures under the Semiconductor Initiative shall be pursuant to applicable laws, executive orders, and regulations followed by the Department of Defense. There is apparently no similar provision for the superconducter initiative and the human genome initiative, the subjects of Titles I and II of S.1480. Thus, if the DOD Authorization bill is enacted, technology transfer regulations implementing Title III (Semiconductor initiative) would need to be harmonized with the requirement to follow laws, executive orders, and regulations followed by the Department of Defense. We are not clear on the scope of this requirement and do not know which of DOE's laws and regulations would be affected by it, if any. We favor deletion or clarification of the DOD Authorization bill provision on technology transfer. As written, it would seem to conflict with the intellectual property provisions of S.1480.

8. If S.1480 (as amended) were passed, what significant changes would occur in current DOE technology transfer regulations?

If S.1480 (as amended) were passed, the last vestiges of DOE management authority over important intellectual property-related aspects of laboratory operations would be swept away, with grave consequences for national security.

Public Law 96-517 as amended and Department of Commerce regulations, 37 CFR 401, "Rights to Inventions Made by Nonprofit Organizations and Small Business Firms," which largely govern rights to inventions made at DOE GOCO facilities operated by nonprofits, including LLL and LANL, currently provide an exemption for weapons-related programs (and naval nuclear propulsion programs) at nonprofit operated labs primarily dedicated to those programs. This exemption would be removed by S.1480. This would result in those contractors having the right to elect ownership of inventions that may be related to nuclear weapons and other highly sensitive technology made at such labs. Removal of the exception for weapons related and naval nuclear propulsion inventions could thereby lead to the loss or proliferation of vital military secrets as well as contribute to the growing diversion of laboratory attention from weapons mission objectives to activities in the commercial arena and possibly to a lack of cooperation between laboratories.

trademarks, trade secrets, mask works and other intellectual property rights would require significant changes in applicable regulations concerning technical data rights. DOE data rights policy, particularly in view of statutory requirements for dissemination of the results of DOE-sponsored research and development which is unclassified and not sensitive, generally provides for the Government having unlimited rights in data first produced under a DOE-sponsored arrangement. These requirements would appear to conflict with authority to have contractors maintain trade secret rights to data first produced under a cooperative research and development agreement.

The provisions of S.1480 that would allow all GOCO contractors participating in the Initiative of S.1480 to retain title to intellectual property rights would, if enacted, require amending of DOE's regulations, 41 C.F.R. 9-9, concerning rights in inventions made under DOE contracts, grants and other arrangements.

Further amendments to intellectual property regulations concerning DOE would be required to implement the provision for waiver of the Government's license rights and to implement provisions regarding disposition of royalty income arising from licensing of inventions retained by contractors, march-in-rights, and the policy for promoting exclusive use of such technologies by U.S. industries.

In the technologies covered by S.1480, contractors operating DOE national laboratories would have authorities to enter into cooperative agreements as provided for Government-operated laboratories in section 11 of the Stevenson-Wydler Technology Innovation Act of 1980, including the authority to make agreements relating to intellectual property rights, and including waiving in advance, in whole or in part, any rights of the Federal Government to inventions made under such cooperative agreements by a collaborating party. DOE would have little if any authority to manage the transfer of technology under such agreements. DOE Contractor-operated laboratories currently have authority to enter into agreements with industry subject to DOE management control (commonly called "Work for Others" arrangements or User Facility Arrangements). DOE currently has in place class waivers for such work for others and user facilities arrangements outside the weapons mission area generally providing for the industrial participant to have the right to elect invention rights. S.1480, if enacted, would pose a conflict with such participant's rights under the class waivers by allowing the contractor operating the facility to make decisions concerning disposition of invention rights made by a collaborating party.

Extending the patent policy of 35 U.S.C. 202(a) and (c) and of section 11 of Stevenson-Wydler to apply also to copyrights,

9. How would these changes affect the flow of information from the laboratories?

There is concern at DOE that passage of S.1480 could significantly affect the flow of information from and between DOE laboratories. For weapons applications of the technologies subject to S.1480, particularly superconductor and semiconductor technology, elimination of the exemption from 35 U.S.C. 202 for weapons program and naval nuclear propulsion inventions arising from laboratories primarily dedicated to weapons programs (and naval nuclear propulsion programs) subjects such inventions (unless otherwise excepted) to automatic contractor ownership. In the view of the contractor and its personnel retaining rights, technology transfer incentives would likely appear paramount to the national security aspects of the development. A commercial-like atmosphere whereby technical personnel may be reluctant to share such information with other weapons-related laboratories in order to maintain and enhance a particular contractor's proprietary position is likely to develop. Indeed, it is this and similar concerns that resulted in Congress' maintenance of the exception for labs primarily dedicated to weapons and naval nuclear propulsion in Pub. L. 98-620.

Under current Department of Commerce regulations implementing Pub. L. 98-620, nonprofit operators of DOE laboratories primarily dedicated to weapons programs (e.g., LANL, LLNL) would likely be able to retain any inventions that are the subject of Title II of S.1480 (Mapping the Human Genome). For superconductor and semiconductor inventions arising from those labs, many are likely to be electable, or at least determinable, (allowing a case-by-case review) under current law and regulations. Allowing automatic retention of rights in areas that may be closely related to national security could seriously inhibit exchange of information among technical persons at weapons laboratories. This concern is amplified by the provisions of S.1480 to extend the patent policy of 35 U.S.C. 202 and section 11 of Stevenson-Wydler to other forms of intellectual property, including copyrights and trade secrets. Allowing contractors to maintain research and development data developed at national laboratories as a company trade secret would clearly have a negative effect on the flow of information from and between the laboratories.

The DOE position in these areas is often contrasted with that of the Department of Defense, which has traditionally followed a policy of contractor retention of patent rights. However, DOD weapons laboratories are generally Government-owned and Government-operated (GOGO), that is, run by Government employees under strict codes of conduct and under a chain of command leading to the head of the agency, in contrast with DOE GOCO labs that are contractor operated. For DOD GOGO weapons labs, the issue of contractor retention of rights and consequent effect on information flow among laboratories does not arise.

Even for non-weapons applications of the subject technologies, where national security concerns are not present, a policy of automatic contractor retention of trade secret rights in inventions arising at national laboratories would have a stifling effect on dissemination and flow of technical information at the labs. Such a policy would also conflict with statutory provisions pertaining to DOE requiring dissemination of the results of DOE sponsored research and development (see e.g., 42 U.S.C. 5817 (section 107(e) of the Energy Reorganization Act of 1974)).

Q.10. Provide for the record the Department's technology transfer activities directed at encouraging:

- o industrial participation?
- o academic community participation?
- o scientific community participation?

A. The following are the Department's technology transfer activities which provide opportunities for industry to work in close collaboration with DOE laboratories:

- o Technical personnel exchange in areas of mutual interest;
- o Cooperative projects with the private sector;
- o R&D contracts with industry, including cost-shared agreements;
- o Scientific user facilities at DOE laboratories;
- o Patent licensing to facilitate technology adoption and use in the U.S. private sector;
- o Consulting by laboratory scientists;
- o Industry participation on advisory and review committees;
- o Technical information exchange through scientist-to-scientist communication, e.g. conferences and visitors to laboratories;
- o Technical documents and broad dissemination of scientific information;
- o R&D "work for others" for private sector firms that requires the special capabilities and unique facilities of the national laboratories;
- o Small Business Innovation Research Program;
- o Centers for collaboration involving industry, universities and laboratories.

The following are examples of the Department's science transfer activities which provide opportunities for the academic community and the scientific community to work in close collaboration with DOE laboratories:

- There are over 2,000 visiting faculty and students participating in scientific educational programs for all or part of a year at the DOE laboratories.
- Four unique high school science honors research programs were held this year at national laboratories.
- Support for undergraduate and graduate student research is being expanded and will include a semester-length research program for 400 - 500 undergraduate students at five national laboratories.
- Over 2,000 university research scientists carry out research at the Department's user research facilities.
- Several DOE laboratories are involved in joint research programs with universities.
- Joint laboratory and university appointments occur at the national laboratories. A few laboratories like Lawrence Berkeley and Ames Laboratories are located on or near college campuses. All national laboratories have long-standing relationships with nearby universities and colleges.
- University researchers participate on peer review panels of research funded by the Department.
- Centers for collaboration involving industry, universities, and laboratories.

Q.10a. Do you believe the technology transfer program in the Department is run in the most effective manner? What changes could be brought about to make it run more efficiently? How do your regulations differ from those in the Department of Commerce?

A. DOE's technology transfer program has come a long way in the last 5 years, but there certainly are numerous ways in which it can be strengthened and developed further to provide additional opportunities to work with the Department and its laboratories. DOE's technology transfer efforts could be enhanced by expanding the laboratories' technology transfer programs and creating additional opportunities for the laboratories to work with industry and universities in identifying and transferring commercially attractive technology. This enhancement could be accomplished by the following measures, many of which currently are being pursued by DOE:

- Expand the industry-laboratory technology exchange program, which funds industry researchers to work at DOE laboratories thereby exchanging valuable information and expertise.
- Expand the technology transfer initiatives program in which highly leveraged seed funding would be made available for innovative technology transfer proposals developed by DOE laboratories.
- Complete implementation of the class patent waivers that would allow laboratory contractors to elect to take title to selected inventions and patents deriving from federally funded R&D.
- Expand science transfer efforts with universities to build upon the basic R&D and scientific user facilities at DOE laboratories.
- Reemphasize a DOE policy that encourages the development of regional industry, university, and State and local government partnerships with major DOE laboratories.

- Encourage expansion of laboratory Technical Volunteers Programs utilizing laboratory retirees to respond to requests from local government agencies, schools, and other organizations needing technical help.
- Develop programs to evaluate effectiveness and reward excellence in technology transfer.

We are not aware of any Department of Energy (DOE) or Department of Commerce (DOC) regulations pertaining to, or affecting, the transfer of technology from Federal laboratories to the private sector other than patent and patent licensing regulations. DOE follows DOC's regulations implementing Public Law 98-620 concerning patent rights of small business and nonprofit contractors, 37 C.F.R. 401, and also follows Commerce's regulations for licensing of patents, 37 C.F.R. 404. With regard to large business contractors, DOE follows a patent waiver policy contained in 41 C.F.R. 9-9 providing for title in the Government of inventions arising from contracts with large businesses unless a patent waiver is granted. The statutory basis for DOE's patent waiver policy is unique to DOE (42 U.S.C. 5908), and thus not followed by the Department of Commerce or other agencies.

10b. Please list the steps taken by the Department once a request is submitted by a national laboratory to initiate a licensing agreement between that lab and a private company. Also, indicate, after each step, an estimated and realistic timeframe required to complete this step.

National laboratories generally do not submit requests to initiate a licensing agreement between the laboratory and a private company.

Q. 11. In light of the rapid advances into superconducting materials, how does the Department intend to take advantage of these discoveries? How will these and future discoveries be integrated into the Department's basic research and development efforts?

A. The Department of Energy has moved aggressively to take advantage of these discoveries. In January of 1987, soon after the discoveries were announced, the Office of Energy Research's Office of Basic Energy Sciences had its first meeting to coordinate the work of researchers in superconductivity supported by the Division of Materials Sciences who had started work on the new high temperature superconductors. This meeting led to a substantial redeployment of effort of researchers in related areas, such as synthesis, ceramic processing, and characterization, toward the high temperature superconductors. The second and third meetings to coordinate these efforts were held in February and May respectively. A fourth meeting was held September 21 and 22. A Federal conference on applications of superconductivity was held in July bringing together 1200 participants. This meeting was sponsored by the Department of Energy's Office of Conservation and Renewable Energy with the strong leadership of the Secretary of Energy. The Office of Conservation and Renewable Energy has carried out assessments of the potential impact of these new materials on transmission lines, generators, and electrical energy storage; and the Basic Energy Sciences Advisory Committee is assessing the potential impact in High Energy Physics applications. A subcommittee of the Energy Materials Coordinating Committee has been established to coordinate the Department's efforts. Coordination with other federal agencies is done through a subcommittee of the Committee on Materials of the Office of Science and Technology Policy.

The meetings held to coordinate the research efforts of the Department, mentioned above, have been part of the process used to integrate these discoveries into the Department's basic research program. In addition, two joint laboratory programs were established to make the best use of the combined strengths of the Department's laboratories. One of these, among Argonne National Laboratory, Ames Laboratory, and Brookhaven National Laboratory, is focused on understanding the processing of these materials into conductor forms. The other, which is among Oak Ridge National Laboratory, Lawrence Berkeley Laboratory, and Los Alamos National Laboratory, is focused on alternate processing methods, synthesis and thin films. Facilities such as neutron sources, synchrotrons, and electron microscopes supported by Basic Energy Sciences are a very important part of the research program and are used to determine the structure and to characterize the materials. As part of the President's Superconductivity Initiative, three Superconductivity Research Centers have been established, one each at Ames Laboratory, Argonne National Laboratory, and Lawrence Berkeley Laboratory. The center at Ames Laboratory is charged with gathering and disseminating basic research information. The center at Argonne will do the same for conductor applications and the one at Berkeley for thin films applications. Also as part of the President's initiative, a computer-based data and information center has been initiated by the Office of Conservation and Renewable Energy and established at the Office of Scientific and Technical Information in Oak Ridge, Tennessee. These research centers and the data center are part of the Department's program to ensure that information regarding these materials is readily available not only for the Department's own development efforts but also for the private sector. To further interactions with the private sector and to ensure rapid commercialization of the Department's efforts, the Secretary of Energy charged Los Alamos National Laboratory to develop ways to expedite the transfer of technology to the private sector. The assessments mentioned above will serve to integrate these discoveries into the development efforts of the Department and will guide the development programs by identifying the potential economic impact and the technological problems requiring solution for the specific technologies addressed in the assessments.

Q.12. Do you intend to work with the Electric Power Research Institute (EPRI) in carrying out R&D on Electric Power Applications of superconductivity? How will this take place?

A. The Department of Energy has already initiated cooperative efforts with the EPRI in the area of superconductivity. Over the past years, the superconducting magnetic energy storage research has been closely coordinated. With the onset of the new high temperature materials, this cooperation has been extended to include all applications on electric power systems.

Q. 13. To what extent should the U.S. participate or encourage international collaboration in R&D and commercialization?

A. With respect to basic research, international collaboration has already proven valuable. For example, Japanese and U.S. scientists collaborated in experiments at Brookhaven National Laboratory that may shed light on the mechanism of conductivity in the new class of high-temperature superconductors. Also we should not forget that the seminal work on these materials was done in Switzerland, and confirmed by Japanese scientists following the lead of the Swiss scientists, and then the U.S. group from the University of Houston discovered the superconductor materials that were superconducting above liquid nitrogen temperatures. It is therefore evident that, in basic research, existing mechanisms to encourage international collaborations and the extent to which these collaborations are occurring appear to be adequate. With respect to commercialization, it is too early to draw meaningful conclusions regarding international collaboration because the properties of these materials are not yet understood or predictable enough to make articles of commerce from them. In some of the Department's development programs, such as in fusion energy, where international collaboration already exists, collaborative development efforts using these materials may be appropriate when the properties of the materials are understood well enough that such a development effort can be contemplated.

Human Genome

14. Please explain how the Department of Energy got involved in research on mapping the human genome. I understand it stems from your research into illnesses resulting from energy-technology—such as radiation effects—and the Department's work in nuclear medicine. But how and when did the Department's directive turn to more extensive medical-related issuess, such as the GenBank and the National Lab Gene Library?

The Biological and Environmental Research program of the Department of Energy has two missions. The first is to develop scientific understanding of the effects of energy technologies; the second is to utilize the Department's unique capabilities and technology for beneficial applications in the biomedical sciences (the nuclear medicine program is an example).

The Department of Energy and its predecessor agencies (the Atomic Energy Commission and the Energy Research and Development Administration) have carried out a major program in genetics research and have funded, since 1946, the world's largest effort to detect genetic effects in human populations, a study of the survivors of the atomic bombs at Hiroshima and Nagasaki. To date, however, all the available methods have provided no documented evidence for the induction (by chemicals or by radiation) of mutations in human germ cells. In order to detect and quantitate mutations in human populations, sensitive new technologies based on more efficient analysis of DNA, the genetic material, are required. A September 1986 report of the Office of Technology Assessment (Technologies for Detecting Heritable Mutations in Human Beings) suggested that Congress could designate a lead agency for research related to detecting and characterizing mutations and suggested "DOE may be the logical choice for a lead agency," because of its lead in funding much of the research on new methods for mutation detection. In short, the new technologies required to rapidly characterize the molecular nature of the human genome are needed to provide more effective measures of damage to the genome. Development of these new technologies represents a new approach to a traditional mission of the Department. Also, as Dr. Wyngaarden pointed out on September 17, these new technologies and new knowledge will give us "new insights into the way environmental factors, for example, radiation, might trigger certain changes in the genetic material that then predispose to certain cancers." "This may lead to whole new strategies of prevention" of the potential health impacts of environmental agents.

The Department's laboratories represent an extremely valuable technological resource and the laboratories have been leaders in applying new technology to biomedical applications. As Dr. Wyngaarden pointed out in his testimony, Los Alamos National Laboratory in 1979 began a DNA sequence database as a pilot project. Based on its success, NIH established GenBank at Los Alamos in 1982.

The National Laboratory Gene Library Project grew out of the invention, at Los Alamos, of flow cytometry. Flow cytometry has numerous applications in evaluation of the impacts of environmental agents on cells and chromosomes. This technology is now widely used in research and clinical laboratories but Los Alamos and Livermore National Laboratories remain world leaders in its further development and application. In recognition of this, NIH has established the National Flow Cytometry Resource at Los Alamos. By the summer of 1983, the two laboratories were receiving numerous requests from biomedical researchers to provide to them specific human chromosomes separated by flow cytometry. Usually these researchers wanted to prepare cloned DNA samples from the separated chromosomes. The Department decided, based on the impossibility of responding to each of these requests, that it would be a useful national service to provide to the research community, DNA libraries of separated human chromosomes. These libraries are made available through a repository funded by the NIH.

15. In your written testimony, you mention a certain number of known genetic diseases—3000. How many of these illnesses are known to be brought on by exposure to, or somehow relating to, energy-technologies?

We do not know that any of the known genetic diseases are brought on by exposure to energy-related agents. Although our understanding of these genetic diseases will surely be greatly increased because of the technologies and resources created in this project, the development of this new understanding regarding known genetic diseases will come about primarily through NIH-supported research. This project will lead to new insights about all human genes and into the genetic contribution to a great many diseases, not only the known genetic diseases.

The Department of Energy, as pointed out above, is primarily interested in applying these technologies and resources for the evaluation of energy-related health impacts (cancer and heritable mutations are currently of primary concern) and for the development of new strategies for the prevention of health impacts due to environmental agents. There are thought to be about 100,000 human genes. Of particular interest to DOE are genes which code for proteins which are involved in the repair of damage to DNA. There are many DNA repair genes. A thorough understanding of the repair of damage to DNA is necessary to evaluate potential mutagenic and carcinogenic agents. DOE is also interested in applying the new technologies to identify individuals who may be particularly sensitive or resistant to environmental agents.

In a broader sense, these technologies and resources are certain to impact all areas of the developing biotechnology industry.

16. What concerns, if any, have been expressed regarding controversial and ethical implications of mapping the genome? How has the Department dealt with these concerns?

There has been discussion in the press regarding the implications of mapping the human genome. It is certainly clear that this new knowledge will have widespread implications for society. There needs to be an informed and responsible national discussion of these implications and how we are to deal with them as a society.

QUESTIONS SUBMITTED BY SENATOR PETE V.DOMENICI

FOR THE DEPARTMENT OF ENERGY

1. DOE has stated that since 1981, there has been a five-fold increase of new companies formed as a spin-off of DOE laboratory technology, with 77 companies formed in 1985-1986.

Provide a chart listing for each of these companies:

-the date the company was formed;

-the time it took for the company to acquire the rights to the technology (i.e. the time duration from the initial waiver request of DOE to the DOE approval);

-the technology the company was based on;

-the current status of the company, whether it is still in existence and whether they have reached the stage of marketing a product or a service;

-the product/process that the company intends to or is currently marketing.

2. The DOE patent waiver process for the National Lab contractors has frequently been cited as unnecessarily bureaucratic, lengthy, and unpredictable.

Provide a list of the pending patent waivers and indicate how long they have been pending. If longer than one year, please state what the reason is for the delay.

List the criteria that are used to evaluate a patent waiver request and the reasons that such a waiver would be denied.

How many patent waiver requests have been denied by DOE during the last year, the last 5 years, and the last ten years?

Is the information related to the patent waiver process, specifically the determination to grant or deny a waiver and the reasons why, available publically? This would certainly be the type of information that would allow the contractor to predict whether such a request was worth their time and effort.

3. Provide the total number of patent lawyers that were employed by DOE in each of the following years: 1980, 1982, 1984, 1985, 1986, and 1987.

4. The new DOE contract with the University of California to cover the operation of the Los Alamos, Berkeley, and Lawrence Livermore Labs, contains some new provisions related to: the patent clause and the three classes of inventions (electables, determinables, and non-electables); the management allowance; and technology transfer. Provide each of these provisions and an accompanying explanation of each provision that describes:

how this provision differs from the one in the previous contract;

what is subject to DOE review and approval and the estimated time for each of these to occur?

whether the respective provision grants new rights to the contractor or requires additional centralized review by DOE (i.e. specifically where has the contract been streamlined and where has DOE management review been added?)

With regard to the determinables class of inventions, explain the process used to handle determinables and the expected timeframe to make the case-by-case decison as to which class it should be handled under?

With regard to the patent clause provision only, how much of the respective lab's research is subject to case-by-case review by DOE under each of the classes of the patent clause and the time required to perform this review?

With regard to the technology transfer provision only, what was the rationale for this provision requiring DOE approval and how does it relate to the current laws and what was requested originally by the University of California?

5. Provide a copy of DOE's current regulations on the patent class waiver process. As necessary, also include an explanation of what it means and how it works.

Q.1. DOE has stated that since 1981, there has been a five-fold increase of new companies formed as a spin-off of DOE laboratory technology, with 77 companies formed in 1985-1986.

Provide a chart listing for each of these companies:

- The date the company was formed;
- The time it took for the company to acquire the rights to the technology (i.e., the time duration from the initial waiver request of DOE to the DOE approval);
- The technology the company was based on;
- The current status of the company, whether is it still in existence and whether they have reached the stage of marketing a product or a service;
- The product/process that the company intends to or is currently marketing.

A. The attached charts list some 74 new companies, in lieu of the earlier estimate, formed in 1985 and 1986 as a spin-off of DOE technology.

ARGONNE NATIONAL LABORATORY

New Companies Formed from Department of Energy Technology, 1985-1986

Company Name/ Location	Date of Formation	Technology on Which Company Based	Current Status of Company	Product/Process/ Material for Marketing	Patent Waiver Involved	Waiver Granted to	Time Required to Obtain Waiver
Taylor-Fawcett Co. Hinsdale, IL	1986	Accelerator Applications (Ion Beam Analysis)	Active	Chemical Analysis	No		
M. D. Spenser Park Forest, IL	1986	Microprocessing	Active	Pharmaceutical Delivery	Yes	Ralph Benaroya	11 months
Energy Related Tech., Inc., Oak Brook, IL	1986	Engineering--Develop New Energy Research Technologies	Active	R&D Support	No		
Dualtec Corp. Bourbonnais, IL	1986	Control Systems Engineering	Active	Process Control Devices	No		
Buying Time Darien, IL	1986	Time Management Capability	Active	Time Management Procedures and Seminars	No		
American Ceramic Engine Company Bollingbrook, IL	1986	Engine Components	Active	Ceramic Components for Engines	No		
Progress Industries Palos Park, IL	1986	Dye Lasers and Related Equipment	Active	Laser and Related Equipment	No		
Freedom Enterprizes Bianco, TX	1986	Management Assistance and Business Computing	Active	Business Assistance to New Start-ups	No		

ARGONNE NATIONAL LABORATORY (continued)

New Companies Formed from Department of Energy Technology, 1985-1986

Company Name/ Location	Date of Formation	Technology on Which Company Based	Current Status of Company	Product/Process/ Material for Marketing	Patent Waiver Involved	Waiver Granted to	Time Required to Obtain Waiver
Health Research Institute Naperville, IL	1986	Trace Analysis of Elements Attracting Behavior	Active	Diagnosis and Therapy for Mentally Ill	No		
Surface Treatment Science, International Hinsdale, IL	1986	Surface Treatment and Analysis	Active	Surface Treatments Tailored to Specific Needs	No		
Al's Home Improvements Naperville, IL	1986	Energy Conservation in Buildings	Active	Modification of Building to Conserve Energy	No		
Data Communication Speciality Downers Grove, IL	1985	Data Communications	Inactive	Data Communications Set-Ups	No		
P. Farber and Associates Willowbrook, IL	1985	Pollution Control	Active	Design of Pollution Control Systems	No		
ROI Associates Glen Ellyn, IL	1985	Chemical, Reactor, Engineering and Other Technology Assessments	Active	Analysis of Problems of Individual Firms	No		
ACCTEK Associates LaGrange, IL	1985	Accelerator Design	Active	Accelerator for Proton Therapy	No		

New Companies Formed from Department of Energy Technology, 1985-1986

Company Name/ Location	Date of Formation	Technology on Which Company Based	Current Status of Company	Product/Process/ Material for Marketing	Patent Waiver Involved	Waiver Granted to	Time Required to Obtain Waiver
Cryolect Scientific Co. Bourbonnais, IL	1985	Chemical Analysis Techniques	Active	Scientific Instruments	No		
CEO Consultants Sacramento, CA	1985	Project Management Systems	Active	Management Systems Consulting	No		
CEMA, Inc. Western Springs, IL	1985	Project Management Systems	Active	Training and Consulting on Project Management Computer Systems	No		
System Simulation and Analysis, Inc. Western Springs, IL	1985	Reactor Safety Simulation	Active	Thermal Modeling	No		
Enerteq Sciences, Incorporated Western Springs, IL	1985	Energy Systems Design and Analyses	Active	Technical Energy Consulting	No		
Large Scale Biology Corp. (formerly Proteus Technologies, Inc.) Rockville, MD	1985	Biomedical Research	Active	Human Protein Index Mapping	No		

BROOKHAVEN NATIONAL LABORATORY

New Companies Formed from Department of Energy Technology, 1985-1986

Company Name/ Location	Date of Formation	Technology on Which Company Based	Current Status of Company	Product/Process/ Material for Marketing	Patent Waiver Involved	Waiver Granted to	Time Required to Obtain Waiver
Alkem Cutchogue, NY	1985	Low-Cost Solar Collectors	Active	Hybrid Power System	No		
International Resources Group East Setauket, NY	1986	Energy Management Systems Analyses	Active	Energy Analysis Agroforestry Agriculture Health Planning	No		
TRIAD Research, Incorporated Arlington, VA	1985	Modeling Systems Analyses	Inactive	Unknown	No		

New Companies Formed from Department of Energy Technology, 1985-1986

Company Name/ Location	Date of Formation	Technology on Which Company Based	Current Status of Company	Product/Process/ Material for Marketing	Patent Waiver Involved	Waiver Granted to	Time Required to Obtain Waiver
Quantum Optics, Incorporated Emeryville, CA	1986	Materials Development	Active	Transparent Insulating Glass	Yes	Hunt and Tamari	10 months
ISM Technology San Diego, CA	1986	Ion Implantation	Active	Ion Implantation and Services	Yes	Ian Brown	Pending
Horowitz and Nesbit Oakland, CA	1986	Electronics	Active	Fabrication of Wire Arrays	Yes	Horowitz and Nesbit	8 months
Energy Technology Piedmont, CA	1985	Energy Conversion	Active	Heat Pump	No		
Morgan Systems Berkeley, CA	1985	Computer Software	Active	Building Energy Systems Software	No		
Omega Energy Howard, CA	1986	Lighting	Active	Film Coatings for Lamp Fixtures	No		
Harmax, Inc. Los Angeles, CA	1986	Energy Conservation	Active	Blower Doors	No		
Infiltech Oakland, CA and Virginia	1985	Energy Conservation	Active	AC Pressurization Apparatus	Yes	Modera and Sherman	11 months

New Companies Formed from Department of Energy Technology, 1985-1986

Company Name/ Location	Date of Formation	Technology on Which Company Based	Current Status of Company	Product/Process/ Material for Marketing	Patent Waiver Involved	Waiver Granted to	Time Required to Obtain Waiver
Polarization Imaging Corp. New Mexico	1985	Optics	Inactive	Differential Imaging Microscope	No		
Photon Diagnostics	1985	Medicine	Inactive	Radiopharmaceutical	Yes	University of California	8 months

LAWRENCE LIVERMORE NATIONAL LABORATORY

New Companies Formed from Department of Energy Technology, 1985-1986

Company Name/ Location	Date of Formation	Technology on Which Company Based	Current Status of Company	Product/Process/ Material for Marketing	Patent Waiver Involved	Waiver Granted to	Time Required to Obtain Waiver
Advanced Optics Incorporated	1985	Optics Thin Film Coating Chemical Deposition	Active	Coated Optics and Various Applications	No		

New Companies Formed from Department of Energy Technology, 1985-1986

Company Name/ Location	Date of Formation	Technology on Which Company Based	Current Status of Company	Product/Process/ Material for Marketing	Patent Waiver Involved	Waiver Granted to	Time Required to Obtain Waiver
Accsys Technology, Inc. Pleasanton, CA	1985	Accelerator Technology (PIon Generator for Medical Irradiation)	Active	Production of Radioisotopes used in PET (Positron Emmision Tomography). Developed Small Portable Accelerator for PET Isotope Production	No		
Rad Alarm, Inc. Brooklyn, NY	1985	Portable Radiation Alarm Equipment	Active	Manufactured Units First Sold in 3/86	No		
Jona Machining Company, Inc. Los Alamos, NM	1985	Percision Machining Techniques	Active	Machine Shop Services	No		
Output Dynamics, Incorporated Los Alamos, NM	1985	Gas Valves	Active	Produces Gas Valves for National Market	No		
Signition, Inc.	1986	Audio Perception Technologies	Active	Research and Development in Artificial Intelligence and Audio Perception Technologies	No		

LOS ALAMOS NATIONAL LABORATORY (continued)

New Companies Formed from Department of Energy Technology, 1985-1986

Company Name/ Location	Date of Formation	Technology on Which Company Based	Current Status of Company	Product/Process/ Material for Marketing	Patent Waiver Involved	Waiver Granted to	Time Required to Obtain Waiver
Mesa Diagnostics Los Alamos, NM	1985	Multiparameter Light Scattering	Active	Laser-based Equipment for Determination and Identification of Viruses and Bacteria	Yes	University of California	5 days
ICAMP Los Alamos, NM	1985	Computer Software Solids Modeler for Computer Measuring	Active	Computer Software and Measuring Devices	No		
Thermomagnetics Devices (Now Astronautics Corp of America)	1985	Magnetic Refrigeration	Active	Cryogenic Refrigeration Equipment	Yes (4)	John Barclay	6 months each
Newport Corp. Fountain Valley, CA	1985	Laser Bollemeter	Inactive	Laser Bollemeter	No		
Pajarito Scientific Los Alamos, NM	1986	Nuclear Assay	Active	Neutron Interrogation of Nuclear Waste	No		

OAK RIDGE NATIONAL LABORATORY

New Companies Formed from Department of Energy Technology, 1985-1986

Company Name/ Location	Date of Formation	Technology on Which Company Based	Current Status of Company	Product/Process/ Material for Marketing	Patent Waiver Involved	Waiver Granted to	Time Required to Obtain Waiver
Anflow Inc. Oak Ridge, TN	1985	Sewage Treatment	Active	Sewage Treatment Facilities	Yes	Martin Marietta/ Energy Systems	4 months
Self Powered Lighting Corp.	1985	Tritium Lights	Active	Safety Lights	No		
Technology Corridor Instruments (Now Delta M Corp.) Oak Ridge, TN	1985	Integrated Heat Generating and Sensing Systems	Active	Thermocouple	Yes	R. McCullough	18 months
ORDELA Oak Ridge, TN	1985	Position Sensitive Proportional Counter	Active	Detectors	No		
AXESS Oak Ridge, TN	1985	Hazardous Material Tracking System	Active*	Software	No		
ALChemIE Oak Ridge, TN	1986	Isotope Separation	Active	Isotopes	No		

New Companies Formed from Department of Energy Technology, 1985-1986

Company Name/ Location	Date of Formation	Technology on Which Company Based	Current Status of Company	Product/Process/ Material for Marketing	Patent Waiver Involved	Waiver Granted to	Time Required to Obtain Waiver
Telerobotics International Knoxville, TN	1986	Remote Manipulation System	Active	Robots	No		
SynCrys Oak Ridge, TN	1986	Eutectic Materials	Active	Research	No		
Vacuum Technology Incorporated Oak Ridge, TN	1986	Vacuum Test Equipment	Active	Vacuum Test Equipment	No		
TEKnowledge Oak Ridge, TN	1986	Intelligent Switch	Unknown	Computer Switch	No		
OES Researches Company Oak Ridge, TN	1986	Heat Exchange	Active	Research Refrigerators	No		

PACIFIC NORTHWEST LABORATORIES

New Companies Formed from Department of Energy Technology, 1985-1986

Company Name/ Location	Date of Formation	Technology on Which Company Based	Current Status of Company	Product/Process/ Material for Marketing	Patent Waiver Involved	Waiver Granted to	Time Required to Obtain Waiver
Chemchek Instruments, Inc. Richland, WA	1986	Kinetic Phosphorimetry	Active	Instruments for Measuring Uranium in Bioassays	No		
Lee Scientific Incorporated Salt Lake City, UT	1985	Supercritical Fluid Chromatography	Active	Analytical Instrument for Chemistry	No		
Suprex Company Philadelphia, PA	1985	Supercritical Fluid Chromatography	Active	Analytical Instrument for Chemistry	No		

New Companies Formed from Department of Energy Technology, 1985-1986

Company Name/ Location	Date of Formation	Technology on Which Company Based	Current Status of Company	Product/Process/ Material for Marketing	Patent Waiver Involved	Waiver Granted to	Time Required to Obtain Waiver
Hulme Mathematics Albuquerque, NM	1985	Fault Tree Analysis of Complex Systems (SETS Code)	Active	Service Contracts in Fault Analysis	No		
International Energy Associates Ltd. Albuquerque, NM	1985	Systems Analysis	Active	Quality Assurance Software	No		
Logic Analysts Albuquerque, NM	1985	Math. Modeling	Active	Math. Study Contracts	No		
Integrated Security Systems Albuquerque, NM	1985	Process to Analyze Vulnerability of Security Systems	Active	Vulnerability Assessments of Security Systems	No		
Innovative Silicon Technologies, Corp.	1986	Silicon Wafer Holding	Active	Wafer Handling and Placement Tool	Yes	Linda Witherspoon	5 months
Semiconductor Bridge Albuquerque, NM	1986	New Explosive Ignitor Technology	Active	Explosive Ignitor	Yes	Pending	

SANDIA NATIONAL LABORATORIES (continued)

New Companies Formed from Department of Energy Technology, 1985-1986

Company Name/ Location	Date of Formation	Technology on Which Company Based	Current Status of Company	Product/Process/ Material for Marketing	Patent Waiver Involved	Waiver Granted to	Time Required to Obtain Waiver
PDA Engineering Albuquerque, NM	1986	Structural Mechanics and Advanced Materials	Active	Engineering Research	No		
Silachem Albuquerque, NM	1986	Silicon Chemistry	Active	Photoconductive Materials; Photoresists; Ceramic Precursors	Yes	John Zeigler	6 months

New Companies Formed from Department of Energy Technology, 1985-1986

Company Name/ Location	Date of Formation	Technology on Which Company Based	Current Status of Company	Product/Process/ Material for Marketing	Patent Waiver Involved	Waiver Granted to	Time Required to Obtain Waiver
Glasstech Solar Arvada, CO	1985	Amorphous Silicon Solar Panel	Active	Turn-key Production Systems to Domestic and Foreign Customers	No		
Rocky Mt. Analytical Research Laboratories, Inc. Golden, CO	1985	Electron Spectroscopy and Surface Analysis	Active	Analytical Services	No		
Syngas, Inc. Golden, CO	1985	Wood Gasifier Systems for Heat and Diesel Fuels	Active	Systems for Gas production and Co-generation	No		
International Bio-Resources, Incorporated Lakewood, CO	1985	Aquaculture and Shellfish Farming	Active	Inland Aquaculture	No		
Industrial Solar Technology Denver, CO	1986	Solar Thermal Concentrators	Active	Solar Thermal Systems	No		
Ocean Genetics Santa Cruz, CA	1986	Culture of Microalgae	Active	Commerical Shoreline Algae Farm	No		
Pyrotech Corp. Leawood, KA	1986	Ablative Fast Pyrolysis of Biomass	Active	Converting Wood Wastes to Pyrolysis Oils and Liquid Fuels	No		

2. The DOE patent waiver process for the National Lab contractors has frequently been cited as unnecessarily bureaucratic, lengthy, and unpredictable.

Provide a list of the pending patent waivers and indicate how long they have been pending. If longer than one year, please state what the reason is for the delay.

ALBUQUERQUE OPERATIONS OFFICE

WAIVER NO.	PETITIONER	REASON FOR DELAY	DATE RECEIVED	STATUS	GROUP	SUBJECT MATTER
W(I)-85-091	Sandia Corp.	Waiting for additional information concerning funding; contractor had requested request be held in abeyance	11/13/85	Pending	AL	Strained-Layer Superlattice (SLS) Tech. S-56,737
W(I)-85-093	Sandia Corp.	Waiting for additional information concerning funding; contractor had requested request be held in abeyance	11/13/85	Pending	AL	Strained-Layer Superlattice (SLS) Tech. S-58,874
W(I)-85-094	Sandia Corp.	Waiting for additional information concerning funding; contractor had requested request be held in abeyance	11/13/85	Pending	AL	Strained-Layer Superlattice (SLS) Tech. S-59,800
W(I)-85-095	Sandia Corp.	Waiting for additional information concerning funding; contractor had requested request be held in abeyance	11/13/85	Pending	AL	Strained-Layer Superlattice (SLS) Tech. S-59,815

WAIVER NO.	PETITONER	REASON FOR DELAY	DATE RECEIVED	STATUS	GROUP	SUBJECT MATTER
W(I)-85-096	Sandia Corp.	Waiting for additional information concerning funding; contractor had requested request be held in abeyance	11/13/85	Pending	AL	Strained-Layer Superlattice (SLS) Tech. S-61,200
W(I)-85-097	Sandia Corp.	Waiting for additional information concerning funding; contractor had requested request be held in abeyance	11/13/85	Pending	AL	Strained-Layer Superlattice (SLS) Tech. S-61,253
W(I)-87-067	Univ. of CA	Awaiting Headquarter's Decision	07/21/87	Statement of Considerations 08/25/87	AL	Biological Particle Identification Apparatus
		CHICAGO OPERATIONS OFFICE				
W(I)-84-071 CH-0352	Midwest Research Institute	Held in abeyance pending expected regulations regarding Pub. L. 98-620, class waiver for GOCOs, and modification of organizational conflict of interest clause	10/23/84	Pending	CH	RIM Drive Multiplexed Solar Tracking System S-51.751

WAIVER NO.	PETITIONER	REASON FOR DELAY	DATE RECEIVED	STATUS	GROUP	SUBJECT MATTER
W(I)-85-012 CH-0384	Princeton Univ.	GOCO request based solely on passage of 98-620 predates Nov. 1984 - Univ. now preparing additional information	02/28/85	Statement to HQ 05/03/85 (New SOC to be prepared)	CH	X-Ray Laser S-61,312
W(I)-85-102 CH-0412	Univ. of Chicago	Awaiting agreement of Univ. of Chicago to reimburse DOE for expenses - Now subject to steel initiative issue	11/14/85	Pending	CH	Horizontal Electromagnetic Casting of Thin Metal Sheets S-62,969
W(I)-86-064 CH-0426	EG&G Idaho	Investigation of agreement between EG&G Idaho and metallurgical instruments group to obtain waiver and assign all inventions of INEL in this technology to MIG	06/17/86	Pending	CH	Inertial Separation of Atomized Particles to Yield Ultra Fine Powders S-65,030
W(I)-86-103 CH-0445	University Research Association		10/24/86	SOCF on	CH	Light Collection BaF_2 by Surface Preparation S-65,003
W(I)-87-005 CH-0449	Iowa State Univ.	Waiver sent to HQ on 03/24/87 - Need more information to support grant	02/13/87	Pending	CH	Inductively Coupled Plasma Coating S-63,372

WAIVER NO.	PETITIONER	REASON FOR DELAY	DATE RECEIVED	STATUS	GROUP	SUBJECT MATTER
W(I)-87-012 CH-0451	Iowa State Univ.	Contractor was advised that more information is needed to support grant of waiver	03/16/87	Pending Waiver to HQ 05/14/87	CH	R-E-Iron Alloys by Thermite Rod S-63,373
W(I)-87-013 CH-0452	Iowa State Univ.	Contractor was advised that more information is needed to support grant to waiver	03/16/87	Pending	CH	Acoustic Resonator and Method S-61,929 Division of S-59,673
W(I)-87-014 CH-0453	Iowa State Univ.	Contractor was advised that more information is needed to support grant to waiver	03/16/87	Pending	CH	Acoustic Resonator and Method S-59,673
W(I)-87-015 CH-0454	Iowa State Univ.	Contractor was advised that more information is needed to support grant to waiver	03/16/87	Pending	CH	Cu-Ta Alloy S-61,930
W(I)-87-016 CH-0456	Iowa State Univ.	Has been Lic. by HQ - Waiver will not be granted	03/16/87	Pending	CH	Helium Afterglow Detector S-61,273
W(I)-87-019 CH-0458	Iowa State Univ.	Contractor was advised that more information is needed to support grant to waiver	02/16/87	Pending	CH	Laser Ion Source for Solids S-65,048
W(I)-87-020 CH-0459	Iowa State Univ.	Contractor was advised that more information is needed to support grant to waiver	02/16/87	Pending	CH	Single Event Mass Spectrometry S-65,049

WAIVER NO.	PETITIONER	REASON FOR DELAY	DATE RECEIVED	STATUS	GROUP	SUBJECT MATTER
W(I)-87-021 CH-0455	Iowa State Univ.	Contractor was advised that more information is needed to support grant to waiver	03/16/87	Pending	CH	Copper Tantalum Ally S-60,251 S-61,930 is a Divisional
W(I)-87-028 CH-0463	Associated Universities	Letter sent asking for more information	02/09/87	Pending	CH	Process for Producing Astine-211 for Radio-pharmaceutical Use S-60,258
W(I)-87-033 CH-0464	Univ. of Chicago		05/01/87	Pending	CH	Solid Oxide Fuel Cell S-56,699
W(I)-87-034 CH-0465	Univ. of Chicago		05/01/87	Pending	CH	Solid Oxide Fuel Cell S-60,679
W(I)-87-035 CH-0466	Univ. of Chicago		05/01/87	Pending	CH	Solid Oxide Fuel Cell S-60,680
W(I)-87-036 CH-0467	Univ. of Chicago		05/01/87	Pending	CH	Solid Oxide Fuel Cell S-60,688
W(I)-87-037 CH-0468	Univ. of Chicago		05/01/87	Pending	CH	Solid Oxide Fuel Cell S-65,410
W(I)-87-038 CH-0469	Univ. of Chicago		05/01/87	Pending	CH	Solid Oxide Fuel Cell S-66,028
W(I)-87-052 CH-0475	Iowa State Univ.		06/12/87	Pending	CH	Surface Treatments for Cu Alloys S-64,643
W(I)-87-053 CH-0476	Iowa State Univ.		06/17/87	Pending	CH	Preparing High Purity Vanadium S-58,601

WAIVER NO.	PETITIONER	REASON FOR DELAY	DATE RECEIVED	STATUS	GROUP	SUBJECT MATTER
W(I)-87-070 CH-0483	Iowa State Univ.		06/16/87	Pending	CH	Improving Detection in Data Signal S-66,560
W(I)-87-071	Universities Research Association		04/17/85	Pending	CH	Locking Mechanism for Indexing Device S-55,479
OAK RIDGE OPERATIONS OFFICE						
W(I)-85-032 ORO-207	Martin Marietta	Staffing/Workload Limitations; indicated to be low priority by contractor	11/26/84	Pending	OR	Dynamic Gas Blazer S-59,925
W(I)-85-036 ORO-211	Martin Marietta	Staffing/Workload Limitations; indicated to be low priority by contractor	11/26/84	Pending	OR	Centrifuge Damper Fluids S-60,595
W(I)-85-038 ORO-213	Martin Marietta	Staffing/Workload Limitations; indicated to be low priority by contractor	11/26/84	Pending	OR	Alarm Circuit Optical Interface S-61,826
W(I)-85-047 ORO-222	Martin Marietta	Staffing/Workload Limitations; indicated to be low priority by contractor	11/26/84	Pending	OR	Disposal of High Level Nuclear Waste S-61,111
W(I)-85-059 ORO-224	Martin Marietta	Staffing/Workload Limitations; indicated to be low priority by contractor	11/26/84	Pending	OR	Fiber Reenforced Ceramic Composites S-61,153

WAIVER NO.	PETITIONER	REASON FOR DELAY	DATE RECEIVED	STATUS	GROUP	SUBJECT MATTER
W(I)-85-060 ORO-225	Martin Marietta	Staffing/Workload Limitations; indicated to be low priority by contractor	11/26/84	Pending	OR	Vapor Deposition S-61,825
W(I)-85-061 ORO-226	Martin Marietta	Staffing/Workload Limitations; indicated to be low priority by contractor	11/26/84	Pending	OR	Plastic Semiconductor S-61,853
W(I)-85-065 ORO-230	Martin Marietta	Staffing/Workload Limitations; indicated to be low priority by contractor	04/02/85	Pending	OR	Metallic Glass Composition S-61,831
W(I)-85-066 ORO-231	Martin Marietta	Staffing/Workload Limitations; indicated to be low priority by contractor	04/02/85	Pending	OR	Long Range Ordered Alloys S-61,824
W(I)-85-078 ORO-234	ORAU	Staffing/Workload Limitations	08/14/85	Pending SOC to HQ 06/04/87	OR	1-ALKYL-2- Acetyl-Sn-Glycerol S-60,597
W(I)-85-086 ORO-239	Martin Marietta	Staffing/Workload Limitations; indicated to be low priority by contractor	09/30/85	Pending	OR	Nial and Nifeal for Oxidizing S-63,604
W(I)-86-006 ORO-252	Martin Marietta	Staffing/Workload Limitations; indicated to be low priority by contractor	12/27/85	Pending	OR	Heat Pumps for Thermal Energy Storage System S-62,546

WAIVER NO.	PETITIONER	REASON FOR DELAY	DATE RECEIVED	STATUS	GROUP	SUBJECT MATTER
W(I)-86-008 ORO-254	Martin Marietta	Staffing/Workload Limitations; indicated to be low priority by contractor	12/27/86	Pending	OR	Surface Enhanced Rama Spectroscopy S-61,868
W(I)-86-010 ORO-256	Martin Marietta	Staffing/Workload Limitations; indicated to be low priority by contractor	12/27/86	Pending	OR	Improved Gas Hydrate Coal Storage System S-61,832
W(I)-86-044 ORO-272	Martin Marietta	Staffing/Workload Limitations; indicated to be low priority by contractor	05/19/86	Pending	OR	Architecture for Production Rule Systems S-63,610
W(I)-86-048 ORO-276	Martin Marietta	Staffing/Workload Limitations; indicated to be low priority by contractor	05/19/86	Pending	OR	Triple Effect Absorption Chiller S-63,645
W(I)-86-053 ORO-281	Martin Marietta	Staffing/Workload Limitations; indicated to be low priority by contractor	05/19/86	Pending	OR	Radiohalogenated Branched Carbohydrates S-63,679
W(I)-86-054 ORO-282	Martin Marietta	Lack of manpower indicated to be low priority by contractor	05/19/86	Pending	OR	Advanced System for Production of Biocatalyst Beads S-63,677
W(I)-86-056 ORO-284	Martin Marietta	Staffing/Workload Limitations; indicated to be low priority by contractor	05/19/86	Pending	OR	Triple Effect Absorption Heat Pump Utilizing Two Refrigeration Circuits S-63,687

WAIVER NO.	PETITIONER	REASON FOR DELAY	DATE RECEIVED	STATUS	GROUP	SUBJECT MATTER
W(I)-86-074 ORO-294	Martin Marietta	Staffing/Workload Limitations; indicated to be low priority by contractor	08/26/86	Pending	OR	Novel Ternary Ceramic Alloy S-64,947
W(I)-87-023 ORO-309	Martin Marietta	Staffing/Workload Limitations; indicated to be low priority by contractor	03/20/87	Pending	OR	Ultrasonic Range and Data Telemetry System (USRADS) S-64,901
RICHLAND OPERATIONS OFFICE						
W(I)-86-083	Westinghouse	Awaiting additional information from petitioner concerning its plans and intentions for the specific invention	10/24/86	Pending	RL	Low Friction and Galling Resistant Coatings and Process for Coating S-62,142 and S-62,149

List the criteria that are used to evaluate a patent waiver request and the reasons that such a waiver would be denied.

The criteria used to evaluate a patent waiver request are listed in 41 CFR 9-9.109-6, a copy of which is attached hereto. Prior to the implementation of Pub. L. 98-620 all National Laboratory contracts provided that title to inventions vested in the Government unless a waiver of an identified invention was granted in accordance with 41 CFR 9-9.109-6(c). Recently, these contracts have been modified to allow nonprofit organization National Laboratory contractors to retain title to their inventions as provided by Pub. L. 98-620.

A waiver could be denied if the criteria of 41 CFR 9-9.109-6 were not met or if it was not possible to meet at least one of the objectives of 41 CFR 9-9.109-6(a) by granting the waiver. National Laboratory contractors have been denied waivers because the Government was continuing to develop the invention, because the contractor had no firm plans and intentions to commercialize the invention, and because the invention was important to national security.

How many patent waiver requests have been denied by DOE during the last year, the last 5 years, and the last ten years?

In the past 10 years, DOE has denied 10 waiver requests by National Laboratory contractors. Of this number 9 were denied in the past 5 years and 6 in the past year.

Is the information related to the patent waiver process, specifically the determination to grant or deny a waiver and the reasons why, available publicly? This would certainly be the type of information that would allow the contractor to predict whether such a request was worth their time and effort.

As required by 41 CFR 9-9.109-6(e)(3), all information relating to patent waiver requests including the determination to grant or deny the request and the reasons why, is available to the public. This information is publicly available and may be copied at DOE Headquarters in the Freedom of Information Reading Room.

DOE [illegible] Regulations

be issued by the Assistant General Counsel for Patents when there has been, to his best knowledge and belief, compliance with the patent provisions.

(c) The Patent Counsel assigned to assist the procuring activity will assist Contracting Officers in selecting and negotiating patent provisions and, in the case of field procuring activities, will coordinate such assistance with the Chief Counsel in accordance with established local procedures. Patent Counsel will generally submit Patent Information Sheets and otherwise assist Heads of Procuring Activities, contractors, Contracting Officers, subcontractors and vendors in: reporting of inventions and discoveries; reviewing and providing patent clearance prior to publication or release of reports and proposed technical articles and prior to public release or disclosure of information regarding scientific and technical developments made in the course of or under the contract; handling claims for patent and copyright infringement; preparation of certificates to initiate patent clearance; and the handling of other patent matters.

(d) Patent application filing and determination of rights to inventions and discoveries.

The Assistant General Counsel for Patents or designee shall:

(1) Make the determination that inventions reported under subparagraph (e)(2)(i) of the Patent Rights clause are subject inventions under the contract;

(2) Determine whether and where patent protection will be obtained on inventions;

(3) Represent DOE before domestic and foreign patent offices;

(4) Accept assignments and instruments confirmatory of the Government's rights to inventions, and

(5) Represent DOE in patent and other intellectual property matters including those under these regulations.

§9-9.109-4 Remedies.

If a contractor operating under a Patent Rights clause fails to establish, maintain, or follow effective procedures for identifying and disclosing inventions as required by the Patent Rights clause or fails to correct any deficiency after notice thereof, the Contracting Officer may require the contractor to make available for examination books, records, and documents relating to inventions in the same field of technology as the contract to enable an agency determination of whether there are such inventions, and may invoke the withholding of payments provision if a contractor fails to disclose an invention deemed by DOE to be a subject invention.

§9-9.109-5 Conveyance of invention rights acquired by the Government.

Whenever the Government acquires the entire rights, title, and interest in an invention pursuant to a contract or by operation of law, assignments shall be obtained from the inventor to the Government, with the consent of the contractor, to perfect or confirm the Government's rights. The form of conveyance of title from the inventor to the contractor must be legally sufficient to convey the rights the contractor has required to convey to the Government.

§9-9.109-6 Waivers

(a) General.

(1) The Head of the Agency or designee may waive all or any part of the rights of the United States (other than certain rights prescribed in paragraph (i) of this section) with respect to any invention or class of inventions made or which may be made by any person or class of persons in the course of or under any contract of DOE, if it is determined that the interests of the United States and the general public as set forth in the Atomic Energy Act of 1954, as amended (42 USC 2182), and the Federal Nonnuclear Energy Research and Development Act of 1974 (42 USC 5908), will best be served by such waivers. In making such determinations, the Head of the Agency or designee shall have the following objectives:

(i) Making the benefits of the energy research, development, and demonstration program widely available to the public in the shortest practicable time;

(ii) Promoting the commercial utilization of such inventions;

(iii) Encouraging participation by private persons in DOE's energy research, development, and demonstration program; and

(iv) Fostering competition and preventing undue market concentration or the creation or maintenance of other situations inconsistent with the antitrust laws.

(2) If it is not possible to attain each of these objectives immediately and simultaneously for any one waiver determination, the Head of the Agency or designee will seek to reconcile these objectives in light of the overall purposes of the DOE patent policy which is governed by Section 152 of the Atomic Energy Act of 1954, as amended, and Section 9 of the Federal Nonnuclear Energy Research and Development Act of 1974.

(3) Over time, however, the application of this waiver policy is expected to attain each of these objectives. In addition to the patent policies provided by legislation, and where not inconsistent therewith, the waiver determinations will also be guided by the revised Presidential Memorandum and Statement of Government Patent Policy issued August 23, 1971 (36 F.R. 16887-16892).

(b) Advance waiver.

In determining whether a waiver to the contractor at the time of contracting will best serve the interests of the United States and the general public, the Head of the Agency or designee shall, as a minimum, specifically include as considerations the following:

(1) The extent to which the participation of the contractor will expedite the attainment of the purposes of the program;

(2) The extent to which a waiver of all or any part of such rights in any or all fields of technology is needed to secure the participation of the particular contractor;

(3) The extent to which the work to be performed under the contract is useful in the production or utilization of special nuclear material or atomic energy;

(4) The extent to which the contractor's commercial position may expedite utilization of the research, development, and demonstration program results;

(5) The extent to which the Government has contributed to the field of technology to be funded under the contract;

(6) The purpose and nature of the contract, including the intended use of the results developed thereunder;

(7) The extent to which the contractor has made or will make substantial investment of financial resources or technology developed at the contractor's private expense which will directly benefit the work to be performed under the contract;

(8) The extent to which the field of technology to be funded under the contract has been developed at the contractor's private expense;

(9) The extent to which the Government intends to further develop to the point of commercial utilization the results of the contract effort;

(10) The extent to which the contract objectives are concerned with the public health, public safety, or public welfare;

(11) The likely effect of the waiver on competition and market concentration;

(12) In the case of a nonprofit educational institution, the extent to which such institution has a technology transfer capability and program approved by the Head of the Agency or designee as being consistent with the applicable policies of this section; and

(13) The small business status of the contractor.

(c) Waiver of identified inventions.

In determining whether a waiver to the contractor or inventor of rights to an identified invention will best serve the interests of the United States and the general public, the Head of the Agency or designee shall, as a minimum, specifically include as considerations the following:

(1) The extent to which such waiver is a reasonable and necessary incentive to call forth private risk capital for the development and commercialization of the invention;

(2) The extent to which the plans, intentions, and ability of the contractor or inventor will obtain expeditious commercialization of such invention;

(3) The extent to which the invention is useful in the production or utilization of special nuclear material or atomic energy;

(4) The extent to which the Government has contributed to the field of technology of the invention;

(5) The purpose and nature of the invention, including the anticipated use thereof;

(6) The extent to which the contractor has made or will make substantial investment of financial resources or technology developed at the contractor's private expense which will directly benefit the commercialization of the inventor;

(7) The extent to which the field of technology of the invention has been developed at the contractor's expense; .

(8) The extent to which the Government intends to further develop the invention to the point of commercial utilization;

(9) The extent to which the invention is concerned with the public health, public safety, or public welfare;

(10) The likely effect of the waiver on competition and market concentration;

(11) In the case of a nonprofit educational institution, the extent to which such institution has a technology transfer capability and program approved by the Head of the Agency or designee as being consistent with the applicable policies of this section; and

(12) The small business status of the contractor.

(d) Procedures.

(1) All waiver determinations shall be initiated by a written request providing the information set forth in paragraph (e). Such requests may be submitted by existing or potential contractors in the case of requests for an advance waiver and by contractors or employee-inventors in the case of requests for waiver for identified inventions. A request for an advance waiver may also be made for an identified invention which has already been conceived and which reasonably may be first actually reduced to practice in the course of or under a DOE contract. Such waiver requests must include a copy of the patent or patent application covering the identified invention.

(2) A request for an advance waiver shall be submitted to the Contracting Officer or to contractors for their subcontractors at any time prior to execution of the contract or within thirty days thereafter, but should normally be submitted as part of the contract proposal. If the purpose, scope, or cost of the contract is substantially altered by modification or extension, a new waiver request will be required. Accordingly, in such instance, Patent Counsel should advise the Contracting Officer if the purpose, scope, cost, or other factors are so changed upon which the original waiver was granted as to require submission and approval of a new waiver request covering the proposed modification or extension. When advance waivers are granted, the rights set forth in paragraphs (b), (c) and (d) of the clause of §9-9.107-5(a) should be modi-

fied to conform to the waiver granted.

(3) A request for waiver (other than advance waivers) for an identified invention shall be submitted to the Patent Counsel (with notification by Patent Counsel to the Contracting Officer) at the time the invention is reported to DOE, or not later than nine months after conception or first actual reduction to practice, whichever occurs first, or such longer period as may be authorized by the Patent Counsel (with notification by Patent Counsel to the Contracting Officer) for good cause shown in writing by the contractor or inventor.

(4) All requests for waiver received by DOE or its contractors will be forwarded promptly to the Patent Counsel assisting the procuring activity, together with any reference or supporting documents provided by the requestor and any documents or comments provided by the staff of the activity. If the request for waiver appears to contain insufficient information, the Patent Counsel may seek additional information from the requestor to supplement the request and may also seek additional information from other sources. The Patent Counsel will thoroughly analyze the request in view of each of the objectives and considerations set forth in this §9-9.109-6 and shall also consider the overall rights obtained by the Government in the patent, copyright, and data clauses of the contract. Where it appears that a lesser part of the rights of the United States than requested would be more appropriate in view of the policies set forth in this §9-9.109-6, the Patent Counsel should attempt to negotiate a compromise acceptable to both the requestor and DOE.

(5) The Patent Counsel will prepare and recommend a statement of considerations setting forth the rationale for either accepting or rejecting the waiver request. While the statement need not make specific findings as to each and every consideration of paragraph (b) or (c) of this section, it will cover those that raise significant issues and those that are decisive, and it will explain the basis for the recommmended determination. There may be occasions when the application of the various considerations in (b) or (c) of this section to a particular case could cause conflicting results, and in those instances the differences will be reconciled giving due regard to the overall policies set forth in this §9-9.109-6. Field Patent Counsel will coordinate actions on advance waivers with the Chief Counsel of the field procuring activity concerned as required by local procedures.

(6) The statement shall be forwarded to the Assistant General Counsel for Patents to serve as a recommended basis for the waiver determination. The Assistant General Counsel for Patents will also obtain comments from the appropriate DOE program organization to assist the Head of the Agency or designee in the waiver determination. In situations where time does not permit a delay in contract negotiations for the preparation and mailing of a full written statement, field Patent Counsel may submit a recommendation on the waiver verbally to the Assistant General Counsel for Patents and request a verbal determination from the Head of the Agency or designee. Such action shall be promptly confirmed in writing.

(7) In making waiver determinations, the Head of the Agency or designee shall objectively review all requests for waiver in view of the objectives and considerations set forth in this §9-9.109-6. If this determination and the rationale therefor is not accurately reflected in the recommended statement of considerations, a new statement shall be prepared.

(8) Where the request for advance waiver has not been approved prior to the effective date of the contract and the terms and conditions of the waiver have thus not been made a part of the contract, the Contracting Officer shall promptly notify the requestor by letter of the determination of the Head of the Agency or designee, and the basis therefor. If the advance waiver is approved, the letter shall state the scope, terms, and conditions of such waiver. Where the terms and conditions of an approved advance waiver have not been made a part of the contract, the letter shall inform the requestor that the advance waiver shall be effective (i) as of the effective date of the contract for an advance waiver of inventions identified, i.e., conceived prior to the effective date of the contract, or (ii) as of the date the invention is reported with an election by the contractor to retain rights therein, i.e., for an invention conceived or first actually reduced to practice after the effective date of the contract; provided a copy of

the letter is signed and returned to the Contracting Officer by the requestor acknowledging the acceptance of the scope, terms and conditions of the advance waiver. After acceptance by the contractor of an advance waiver, the Contracting Officer shall cause a unilateral no-cost modification to be made to the contract incorporating the terms and conditions of the waiver in lieu of previous patent provisions. Whenever a requested determination has been denied, the requestor may, within thirty days, request reconsideration. Such a request shall include any additional facts and rationale not previously submitted which support the request. Requests for reconsideration shall be submitted and processed in accordance with the procedures set forth in this paragraph (d).

(e) Content of waiver requests.

(1) All requests for waiver shall include the following information (Forms for submitting requests for advance and identified waivers indicating the necessary information may be obtained from the Contracting Officer or Patent Counsel):

(i) The requestor's identification, business address, and, if represented by Counsel, the Counsel's name and address;

(ii) An identification of the pertinent contract or proposed contract and a copy of the contract statement of work or a nonproprietary statement which fully describes the proposed work to be performed;

(iii) The nature and extent of waiver requested;

(iv) A full and detailed statement of facts, to the extent known by or available to the requestor, directed to each of the considerations set forth in paragraph (b) or (c) of this section, as applicable, and a statement applying such facts and considerations to the policies set forth in paragraph (a) of this section. It is important that this submission be tailored to the unique aspects of each request for waiver, and be as complete as feasible; and

(v) The signature of the requestor or authorized representative with the following statement:

> The facts set forth in this request for waiver are within the knowledge of the requestor and are submitted with the intention that the Head of the Agency or designee rely on them in reaching the waiver determination.

(2) Requests for waiver, for identified inventions shall include, in addition to items (1)(i) to (v) above:

(i) The full names of all inventors;

(ii) A statement of whether a patent application has been filed on the invention, together with a copy of such application if filed or, if not filed, a complete description of the invention;

(iii) If a patent application has not been filed, any information which may indicate a potential statutory bar to the patenting of the invention under 35 USC 102 or a statement that no such bar is known to exist; and

(iv) Where the requestor is the inventor, written authorization from the applicable contractor or subcontractor permitting the inventor to request a waiver.

(3) Subject to DOE regulations, requirements, and restrictions on the treatment of proprietary and classified information, all material submitted in requests for waiver or in support thereof will be made available to the public after a determination on the waiver request has been made, regardless of whether a waiver is granted. Accordingly, requests for waiver should not contain information or data that the requestor is not willing to have made public. If proprietary or classified information is needed to make the waiver determination, such information shall not be submitted unless specifically requested by the Patent Counsel.

(f) Record of waiver determinations.

The Assistant General Counsel for Patents shall maintain and periodically update a publicly available record of waiver determinations.

(g) Waiver situations and types of waivers.

(1) The various factual situations which are appropriate for waivers cannot be categorized precisely inasmuch as the appropriateness of a waiver will depend upon the manner in which the considerations set forth in paragraph (b) or paragraph (c) of this section relate to the facts and circumstances surrounding the particular contracting situation or the particular invention in order to best achieve the objectives set forth in paragraph (a) of this section. However, some examples where waivers might be appropriate are in the following:

(i) Cost-sharing contracts;

(ii) Situations in which DOE is providing increased funding to a specific ongoing privately-sponsored research, development, or demonstration project;

(iii) Situations involving the private use of Government facilities where the contractor is funding all or a part of such costs;

(iv) Situations in which the equities of the contractor are so substantial in relation to that of the Government that the waiver is necessary to obtain the participation of the contractor; and

(v) Situations involving contracts with small business concerning their privately developed technology.

(2) As stated in paragraph (a) of this section, waivers may be granted as to all or any part of the rights of the United States to an invention except for certain rights as set forth in paragraph (i) in this section. Accordingly, the waiver of all patent rights that are inherent to an invention, rather than part of the rights, will not necessarily be appropriate. The scope of the waiver will depend upon the relationship of the contractual situation or identified invention to the considerations set forth in paragraph (b) or (c) in order to best achieve the objectives set forth in paragraph (a) of this section. For example, waivers may be restricted to a particular field of use in which the contractor has substantial equities or a commercial position, or restricted to those uses that are not the primary object of the contract effort. Waivers may also be limited to particular geographical locations, may be made effective only for a specified duration of time, or may require the contractor to license others at reduced royalties in consideration of the Government's contribution to the research, development, or demonstration effort.

(3) In advance waivers of identified inventions, the invention will be deemed to be a subject invention and the waiver will be considered as being effective as of the effective date of the contract. This will be true regardless of whether the identified invention had been first actually reduced to practice prior to the time of contracting or would be reduced to practice under the contract. A purpose of such waivers is to clarify and definitize the rights of the parties to such inventions when the facts surrounding the first actual reduction to practice prior to or during the contract are or will be difficult to establish.

(h) Waivers to educational institutions.

(1) Except to the extent that a nonprofit educational institution may be engaged as a contractor operating a Government-owned facility or undertaking other special contracts, the following considerations apply to granting of advance and identified waivers to educational nstitutions having an approved technology transfer program capability. To obtain approval f a technology transfer program, an educational institution shall forward its request to DOE s provided in paragraph (2) below.

(2) A nonprofit educational institution desiring to obtain approval of its technology ansfer program and acceptability shall provide the agency with the following information:

(i) General information concerning the institution, including:

(A) A copy of its articles of incorporation;

(B) A statement of the institution's purpose and aims; and

(C) A statement indicating the source of the institution's funds.

(ii) A copy of the institution's established patent policy, together with the date and manner of its adoption;

(iii) The name, title, address, and telephone number of the officer responsible for administration of patent and invention matters and a description of staffing in this area, including all offices which contribute to the institution's patent management capabilities;

(iv) A description of the institution's procedures for identifying and reporting inventions and a description of the procedures for evaluation of such inventions for inclusion in the institution's promotional program;

(v) A copy of the agreement signed by employees engaged in research and development, indicating their obligation in regard to inventions conceived or first actually reduced to practice in the course of their assigned duties;

(vi) A copy of the invention report form or outlines utilized for preparation of invention reports;

(vii) A statement of whether the institution has an agreement with any patent management organizations or consultants and a copy of any such agreements;

(viii) A description of the plans and intentions of the institution to bring to the marketplace inventions to which it retains title, including a description of the efforts typically undertaken by the institution to license its inventions.

(ix) A description of the institution's past patent application and patent licensing activities, including the following:

(A) Number of inventions reported to the institution during each of the past 5 years;

(B) Number of patent applications filed during each of the past 5 years;

(C) Number of patents obtained during each of the past 5 years;

(D) Number of exclusive licenses issued during each of the past 5 years;

(E) Number of nonexclusive licenses, other than those to sponsoring Government agencies, issued during each of the past 5 years;

(F) Gross royalty income during each of the past 5 years; and

(G) A general description of royalties charged, including minimum and maximum royalty rates.

(x) A list of subsidiary or affiliate institutions which would be covered by an agreement signed by the institution;

(xi) If the institution is a subsidiary or affiliate organization, the name of the other related organization and a description of the relationship;

(xii) The amount of support from each Federal Agency for research and development activities currently being administered by the institution, giving Government agency and breakdown;

(xiii) A statement of the institution's policies with respect to the sharing of royalties with employees; and

(xiv) A description of the uses made of any net income generated by the institution's patent management program.

(3) Before an institution's technology transfer program and capabilities are approved, the institution shall have a technology transfer program which, as a minimum shall include the five criteria listed below. In addition to these criteria, consideration will be given to whether or not other Government agencies have approved an institutional patent agreement with the requesting institution. The six criteria are:

(i) An established patent policy which is consistent with the four policy objectives in §9-9.109-6(a) and is administered on a continuous basis by an officer or organization responsible to the institution;

(ii) Agreements with employees requiring them to assign to the institution or its designee or the Government any invention conceived or first actually reduced to practice by them in the course of or under Government contracts and awards, or assurance that such agreements are obtained prior to the assignment of personnel to Government-supported research and development projects;

(iii) Procedures for insuring that inventions are promptly identified and timely disclosed to the officer or organization administering the patent policy of the institution;

(iv) Procedures for insuring that inventions disclosed to the institution are evaluated for inclusion in the institution's promotional program; and

(v) An active and effective promotional program for the licensing and marketing of inventions.

(vi) The institution has a policy of preferring, in appropriate circumstances, nonexclusive over exclusive licensing and domestic over foreign manufacture.

(4) In connection with requests for advance waivers, an approved technology transfer program and capabilities shall be considered in lieu of commercial, manufacturing, and marketing capabilities which normally reside in industry. Such approval shall not be considered sufficient in and of itself as justifying the granting of an advance waiver to an institution. Approval of the grant of an advance waiver must be viewed in light of the considerations of §9-9.109-6(b) above and the four objectives set forth in §9-9.109-6(a) above.

(5) In requests for identified waivers, however, the fact that an institution with an approved technology transfer program and capabilities has identified an invention and has expressed a desire to commercialize it through a request for a waiver therefor shall normally constitute a presumption that the institution has met the criteria of §9-9.109-6(c) unless it is indicated that under one or more of the criteria the presumption is inapplicable.

(6) If, in addition to a DOE-approved technology transfer program, an educational institution has a written procedure whereby the institution reviews for patentable subject matter papers concerning scientific or technical developments, the following paragraph (g) may be substituted for paragraph (g) of the Patent Rights (short form) clause of §9-9.107-6 or other Patent Rights clause in the contract.

> (g) In order that information concerning scientific or technical developments conceived or first actually reduced to practice in the course of or under the contract is not prematurely published so as to adversely affect patent interest of DOE, the Contractor agrees to screen for patent review each paper prior to its intended publication date. If a Subject Invention is identified by the Contractor in a paper submitted for review, the paper will be submitted to Patent Counsel prior to publication. Publication may be delayed by Patent Counsel for such time as is necessary to file a patent application thereon, up to a maximum of 100 days from the date the paper was submitted to Patent Counsel, or for a period longer than 100 days as mutually agreed.

(i) Terms and conditions of waivers.

Each waiver shall contain, as a minimum, provisions covering each of the following:

(1) Advance waivers shall apply only to inventions reported in accordance with paragraph(e)(2)(i) of the clause of §9-9.107-5(a) and with which is included an election as to whether the contractor will retain the rights waived in the invention, and specifying those countries in which rights will be retained.

(2) Subject to the rights granted in paragraphs (c)(1), (2) and (3) of the Patent Rights clause of §9-9.107-5(a), the contractor or inventor shall agree to convey to the Government, upon request, the entire domestic right, title, and interest in any subject invention when the contractor or inventor, as appropriate:

(i) Does not elect, in accordance with (i)(1) of this section to retain such rights; or

(ii) Fails to have a United States patent application filed on the invention in accordance with paragraph (i)(5) of this section, or decides not to continue prosecution of such application; or

(iii) At any time, no longer desires to retain title.

(3) Subject to the rights granted in paragraph (c)(1), (2) and (3) of the Patent Rights clause of §9-9.107-5(a), the contractor or inventor shall agree to convey to the Government, upon request, the entire right, title and interest in any subject invention in any foreign country, if the contractor or inventor, as appropriate:

(i) Does not elect, in accordance with paragraph (i)(1) of this section, to retain such rights in the country; or

(ii) Fails to have a patent application filed in the country on the invention in accordance with paragraph (i)(6) of this section, or decides not to continue prosecution or to pay any maintenance fees covering the invention. To avoid forfeitures of the patent application or patent, the contractor or inventor shall notify the Patent Counsel not less than 60 days before the expiration period for any action required by the Foreign Patent Office.

(4) Conveyances requested pursuant to paragraph (i)(2) or (3) of this section shall be made by delivering to the Patent Counsel duly executed instruments and such other papers as are deemed necessary to vest in the Government the entire right, title, and interest in the invention to enable the Government to apply for and prosecute patent applications covering the invention in this or the foreign country, respectively, or otherwise establish its ownership of the invention.

(5)(i) With respect to each invention in which the contractor has an advance waiver and elects to retain domestic rights pursuant to paragraph (i)(1) of this section, the contractor shall have a domestic patent application filed within 6 months after submission of the invention disclosure pursuant to paragraph (e)(2)(i) of the clause of §9-9.107-5(a) or such longer period as may be approved by the Patent Counsel for good cause shown in writing by the contractor or inventor. For identified inventions waived to the contractor or inventor, the contractor or inventor shall have a domestic patent application filed within 6 months after the waiver has become effective. With respect to such inventions, the contractor or inventor shall promptly notify the Patent Counsel of any decision not to file an application.

(ii) For each subject invention on which a patent application is filed by the contractor or inventor, the contractor or inventor shall:

(A) Within 2 months after the filing or within 2 months after submission of the invention disclosure if the patent application previously has been filed, deliver to Patent Counsel a copy of the application as filed including the filing date and serial number;

(B) Include the following statement in the second paragraph of the specification of the application and any patents issued on a subject invention, "The Government has rights in this invention pursuant to Contract No. _________ (or Grant No. _________) awarded by the U.S. Department of Energy;"

(C) Within 6 months after filing the application or within 6 months after submitting the invention disclosure if the application has been filed previously, deliver to the Patent Counsel a duly executed and approved instrument fully confirmatory of all rights to which the Government is entitled, and provide DOE an irrevocable power to inspect and make copies of the patent application filed. If, however, a waiver request is pending, delivery of the confirmation instrument may be delayed until a determination of the waiver request is made;

(D) Provide the Patent Counsel with a copy of the patent within 2 months after a patent is issued on the application; and

(E) Not less than 30 days before the expiration of the response period for any action required by the Patent and Trademark Office, notify the Patent Counsel of any decision not to continue prosecution of the application and deliver to the Patent Counsel executed instruments granting the Government a power of attorney.

(iii) For each invention in which the contractor initially elects pursuant to (i)(1) of this section not to retain the rights waived, the contractor shall inform the Patent Counsel promptly in writing of the date and identity of any on sale, public use, or public disclosure of the invention which may constitute a statutory bar under 35 U.S.C. 102, which was authorized by or known to the contractor, or any contemplated action of this nature.

(6)(i) With respect to each invention in which the contractor elects pursuant to (i)(1) of this section to retain the rights waived in a foreign country, or in which the contractor or inventor has obtained a waiver of foreign rights on an identified invention, the contractor or inventor shall have a patent application filed on the invention in that country, in accordance with applicable statutes and regulations, and within one of the following periods:

(A) Eight months from the date of a corresponding United States application filed by the contractor or inventor, or if such an application is not filed, 6 months from the date the invention is submitted in a disclosure pursuant to paragraph (e)(2)(i) of the clause of §9-9.107-5(a);

(B) Six months from the date a license is granted by the Commissioner of Patents and Trademarks to file foreign applications where such filing has been prohibited by security reasons; or

(C) Such longer period as may be approved by the Patent Counsel.

(ii) The contractor or inventor shall notify the Patent Counsel promptly of each foreign application filed and, upon written request, shall furnish an English version of the application without additional compensation.

(7) The contractor or inventor shall, three years after a waiver is effective as to an invention, and at three-year intervals thereafter, and when specifically requested by the Patent Counsel, furnish Patent Counsel a report setting forth:

(i) The commercial use that is being made, or is intended to be made, of said invention, and

(ii) The steps taken to bring the invention to the point of practical application or to make the invention available for licensing.

(8) The Government shall retain at least an irrevocable, nonexclusive, paid-up license to make, use, and sell the invention throughout the world by or on behalf of the Government (including any Government agency) and States and domestic municipal governments, unless the Head of the Agency or designee determines that it would not be in the public interest to acquire the license for the States and domestic municipal governments.

(9) The Head of the Agency or designee has the right to require the granting of a nonexclusive, exclusive, or partially exclusive license to a responsible applicant or applicants, upon terms reasonable under the circumstances:

(i) To the extent that the invention is required for public use by Governmental regulations;

(ii) As may be necessary to fulfill health, safety or energy needs; or

(iii) Such other purposes as may be stipulated in the applicable agreement.

(10) The Head of the Agency or designee has the right to terminate such waiver in whole or in part unless the recipient of such waiver demonstrates to the satisfaction of the Head of the Agency or designee that effective steps have been taken, or within a reasonable time thereafter are expected to be taken, necessary to accomplish substantial utilization of the invention.

(11) The Head of the Agency or designee has the right, commencing four years after a waiver is effective as to an invention, to require the granting of a nonexclusive or partially exclusive license to a responsible applicant or applicants, upon terms reasonable under the circumstances, and in appropriate circumstances to terminate the waiver in whole or in part, following a hearing upon notice thereof to the public, upon a petition by an interested person justifying such hearing;

(i) If the Head of the Agency or designee determines upon review of such material as is relevant, and after the recipient of the waiver or other interested person has had the opportunity to provide such relevant and material information as the Head of the Agency or designee may require, that such waiver has tended substantially to lessen competition or to result in undue market concentration in any section of the United States in any line of commerce to which the technology relates; or

(ii) The recipient of the waiver demonstrates to the satisfaction of the Head of the Agency or designee at such hearing that effective steps have been taken, or within a reasonable time thereafter are expected to be taken, necessary to accomplish substantial utilization of the invention.

(j) Termination.

(1) Any waiver may be terminated at the discretion of the Head of the Agency or designee, in whole or in part, if the request for waiver is found to contain false material statements or nondisclosure of material facts, and such were specifically relied upon in reaching the waiver determination.

(2) Any waiver, as applied to particular inventions, may be terminated at the discretion of the Head of the Agency or designee, in whole or in part, if the requirements set forth in paragraph (i) of this section (terms and conditions of the waivers) have not been fulfilled and such failure is determined by the Head of the Agency or designee to be material and detrimental to the interests of the United States and the general public.

(3) Prior to terminating a waiver under paragraph (j)(1) or (j)(2) of this section, the recipient of the waiver will be given written notice of the intention to terminate the waiver, the extent of such proposed termination and the reason therefor, and a period of 30 days, or such longer period as the Head of the Agency or designce shall determine for good cause shown in writing, to show cause why the waiver should not be so terminated.

(4) All terminations of waivers shall be subject to the rights granted in paragraph (c)(1) of the clause of §9-9.107-5(f), and termination shall normally be partial in nature, requiring the waiver recipient to grant nonexclusive or partially nonexclusive licenses to responsible applicants upon terms reasonable under the circumstances.

(k) Effective date.

Waivers shall be effective on the following dates:

(1) For advance waivers of identified inventions, i.e., inventions conceived prior to the effective date of the contract, on the effective date of the contract, even though the advance waiver may have been requested after that date;

(2) For identified inventions under advance waivers, i.e., inventions conceived or first actually reduced to practice after the effective date of the contract, on the date the invention is reported with the election to retain rights as to that invention; and

(3) For waivers of identified inventions (other than under an advance waiver), on the date of the letter notifying the requestor that the waiver has been granted.

§9-9.110 Reporting of royalties.

In order that DOE may be informed regarding royalty payments to be made by a contractor in connection with any procurement, construction, or operation where the amount of the royalty payment is reflected in the contract price, or is to be reimbursed by the Government, the negotiator shall:

(a) Obtain from the offeror information concerning any royalty payments expected to be made in connection with the proposed procurement, construction, or operation, together with the names of the licensors and either the patent numbers involved or such other information as will permit identification of the patents and patent applications as well as the basis on which the royalties are to be paid;

(b) Obtain from the offeror a certificate that the contract price includes no amount representing the payment of royalty by the offeror directly to others in connection with the performance of the contract; or

(c) Insert in the contract the clause set forth below:

REPORTING OF ROYALTIES

> If this contract is in an amount which exceeds $10,000 and if any royalty payments are directly involved in the contract or are reflected in the contract price to the Government, the contractor agrees to report in writing to the Patent Counsel (with notification by Patent Counsel to the Contracting Officer) during the performance of this contract and prior to its completion or final settlement, the amount of any royalties or other payments paid or to be paid by it directly to others in connection with the performance of this contract together with the names and addresses of licensors to whom such payments are made and either the patent numbers involved or such other information as will permit the identification of the patents or other basis on which the royalties are to be paid. The approval of DOE of any individual payments or royalties shall not stop the Government at any time from contesting the enforceability, validity or scope of, or title to, any patent under which a royalty or payments are made.

3. Provide the total number of patent lawyers that were employed by DOE in each of the following years: 1980, 1982, 1984, 1985, 1986, and 1987.

The number of patent lawyers employed by DOE is as follows:

	1980	1982	1984	1985	1986	1987
Headquarters	18	13	7	7	9	7
Field	32	31	27	25	25	24
Total	50	44	34	32	34	31

Note: The above numbers do not include patent agents. The number of patent agents employed by DOE was 5 in 1980, and 4 for subsequent years. These positions are in the field.

4(a). With regard to the question about the patent clause:

The patent clause (Clause 35) and its Appendix G are attached to these answers.

The three classes of inventions (electable, determinable and not-electable) are set forth in the patent clause and Appendix G.

The patent clause that was recently negotiated with the University is a new clause which made the provisions of Pub. L. 96-517 as amended by Pub. L. 98-620 applicable to the University's operation of a weapons laboratory. This contract clause differs from the previous contract in that the previous contract provided for Government ownership of all patent rights with transfer of title to the University only by the DOE regulatory waiver process, while the new contract gives the University the right to elect to retain title to all inventions which are not weapons related or exceptional circumstance inventions. New ground was broken in permitting the University, as management and operating contractor of a weapons laboratory, to elect title to certain inventions by breaking the research efforts down into three classes: Electable, Not-electable, and Determinable.

The Electable class include all inventions arising out of work in Conservation and Renewable Energy, Energy Research, Propulsion, Fossil Energy, Environmental Safety and Health, Management and Administration, Non-DOD/Non-Intelligence Reimbursables and certain indirectly funded work. The Electable class also included all inventions arising out of Nuclear Energy except for the Multi-Megawatt Space Reactor and Uranium Enrichment. The University may elect to retain title in these Electable inventions by simply notifying DOE of its intent.

The Not-Electable class includes all inventions arising out of Defense Programs, Nuclear Waste, Naval Nuclear, Classified Inventions and Unclassified Sensitive Information under Section 148 of the Atomic Act. The Not-Electable class also includes, as previously stated, inventions arising under Multi-Megawatt Space Reactor and Uranium Enrichment. For the University to obtain title to these inventions, it must submit a waiver request which is processed first by field patent counsel who prepares a Statement of Considerations (SOC) recommending either approval or denial based on statutory and regulatory considerations. The SOC is then transmitted to DOE HQ for review by Defense Programs and DOE Patents for approval or denial based on the above statutory and regulatory considerations and further on the considerations required by §3131 of the 1987 Defense Authorization Act. The DOE has committed in the new contract to process these waivers in less than six months on a best-efforts basis.

The Determinable class includes those inventions which may have national security ramifications and which arise out of DOD and Intelligence Reimbursable Programs, the Laboratory Director's Internal Research and Development Program and Indirect Departmental Research in the areas of chemistry, engineering, and computer science which provides support for weapons research. If the University wishes to obtain title to a Determinable invention, it may inquire of DOE whether it can elect to retain title on a case-by-case basis. DOE has not received such a request but has contractually agreed to exercise its best efforts to provide an answer to such an inquiry within 90 days. Upon receipt by field patent counsel such inquiries will be forwarded to HQ for determination of whether the invention represents a safe technology. The success of this process in 90 days, as well as the waiver process in 6 months, will rely heavily on the Laboratory providing complete information on the potential weapons applications of such inventions and whether disclosure of the invention could constitute a release of sensitive information detrimental to national security. If the invention is determined not to be a safe technology, the University may still seek to obtain title by the formal waiver process.

The major portion of the budget of the weapons laboratories is comprised of weapons funding. However, because of the nature of the research and the fact that much of the weapons funded work is classified, we think it is likely that a majority of the inventions of commercial interest will be in the category that is electable without a case-by-case waiver. However, since the new law (Pub. L. 98-620) and the categories of work under the new patent clause do not yet have a track record, we will need some operating experience to see what portion of inventions fall in the Electable category. For LBL, we would expect virtually all inventions to fall in this category.

4(b). With regard to the question about management allowance:

A copy of the "management allowance" provision (paragraph (c) of CLAUSE 6, Costs and Expenses) of the current renewal contract is enclosed. It replaces an earlier provision by which the University received a "lump sum amount in lieu of indirect costs".

The two provisions differ in the following respects: Under the former "lump sum in lieu of indirect costs" provision, prior to the beginning of each fiscal year, the University and DOE would agree to a provisional amount to compensate the University for indirect costs. As soon as possible after the beginning of the fiscal year, the parties would again negotiate and agree to a fixed lump sum amount, replacing the provisional amount, based on the University's actual costs for the preceding fiscal year in accordance with the costs principles set forth in Federal Procurement Regulations 1-15.3 (now, Federal Acquisition Regulation 31.3). The management allowance to be paid to the University under the current renewal contract, as permitted by DEAR 970.1509-2(b), is a fixed amount for each of the five fiscal years covered by the contract. These amounts were agreed to during negotiations on the renewal contract prior to its effective date.

The "management allowance" provision also requires that a significant portion of each annual amount for management allowance, which is in excess of the amount of lump sum in lieu of indirect costs paid to the University in Fiscal Year 1987, be utilized solely for complementary and beneficial activities related to the Laboratories, examples of which are set forth in the provision.

The only DOE review procedure established by the new provision is the requirement that on December 31 of each year the University provide a report of planned complementary and beneficial activities for the current fiscal year and a summary of such activities carried out in the previous fiscal year. No DOE approval requirements are established.

The management allowance provision streamlines contract administration by eliminating the previous annual two-step agreement process for determining first the provisional amount and later the adjusted fixed lump sum amount in lieu of indirect costs to be paid to the University.

4(c). With regard to the question about technology transfer:

This provision is set forth in Clause 68.

The University requested that technology transfer be included in the Statement of Work as a mission of the Laboratory.

The contract clause on technology transfer is a new provision which recognizes technology transfer as a legitimate function of the Laboratory to be conducted as mutually agreed to by the parties. The Laboratory Technology Transfer Program must be conducted in a manner that is consistent with and on a noninterference basis with the Laboratory's primary mission. This approach is consistent with the Technology Transfer Act of 1986, (Pub. L. 99-502) and Executive Order No. 12591. The Laboratory's Technology Transfer Program must be conducted in accordance with DOE Order 5800.1, R&D Laboratory Technology Transfer Program.

LANL Contract Clauses

(1) The amounts payable to the University for the management allowance for Contracts W-7405-ENG-36, W-7405-ENG-48, and DE-AC03-76SF00098 shall be:

PERIOD	MANAGEMENT ALLOWANCE
October 1, 1987, through September 30, 1988	$12,000,000
October 1, 1988, through September 30, 1989	$12,250,000
October 1, 1989, through September 30, 1990	$12,500,000
October 1, 1990, through September 30, 1991	$12,750,000
October 1, 1991, through September 30, 1992	$13,000,000

Provided, however, that a significant portion of the amount of each annual management allowance listed above, which is in excess of the amount of lump sum in lieu of indirect costs paid to the University in FY87, shall be utilized by the University solely for complementary and beneficial activities related to the Laboratories, including but not limited to the following:

(i) Increased technology transfer activities, including all costs of patent prosecution and invention licensing.

(ii) Increased University supported and sponsored Graduate Student Fellowship programs between University campuses and the Laboratories.

(iii) University funded special equipment and facilities to be utilized by visiting scientists and graduate students at the Laboratories.

(iv) University supported activities necessary to gain increased faculty, student, and general public support of the University's management of the Laboratories.

(v) Increased University and Board of Regents oversight of the operations of the Laboratories.

Prior to December 31st of each fiscal year, the University shall provide to the Contracting Officer a report of planned complementary and beneficial activities for the then current fiscal year and a summary of such activities carried out in the previous fiscal year.

(2) The fixed management allowance for each year shall be paid to the University in equal monthly installments under Contract W-7405-ENG-36 and shall be distributed among the three identified contracts as DOE and the University agree.

CLAUSE 7 - PAYMENTS AND ADVANCES

(a) Installments of the Management Allowance. The University shall receive the management allowance described in paragraph (c) of the clause entitled "Costs and Expenses" in equal monthly installments at the end of each month; provided, however, in the event of termination or expiration, the final installment shall be retained pending compliance with paragraph (e) of this clause.

(b) At any time and from time to time after the execution of this contract, the Government shall advance to the University, without payment of interest thereon by the University, such sums as DOE and the University agree are necessary to finance operations under this contract. All advances of Government funds shall be made by check payable to the University or, at the option of the Government, shall be secured through Letter of Credit procedures authorized by the Fiscal Assistant Secretary, U. S. Treasury Department.

(c) Special Bank Account - Use. Until liquidated as provided herein, any advance and any revenues received by the University in connection with the work under this contract, other than the University's management allowance, shall be deposited in a bank or banks qualified as a depository for federal monies, in a special account in each such bank separate from all other funds and so designated as to indicate clearly to the bank its special character and purpose. The Agreement for Special Bank Account or Accounts shall be consistent with the form and include the provisions set forth in Appendix C of this contract unless otherwise approved by the Contracting Officer. Funds advanced hereunder and the balances of each bank account shall be drawn on by the University solely for the purpose of making payments for the management allowance and costs allowable under this contract or other payments specifically approved in writing by the Contracting Officer. If the Contracting Officer shall at any time determine that the balance in such bank account or accounts exceeds the University's current needs, the University shall make such disposition of the excess as the Contracting Officer may direct.

(d) Title - Rights and Liabilities of Bank. Title to the unexpended balance of any funds advanced and of each bank account established pursuant to this clause shall remain in the Government and be superior to any claim or lien of the bank of deposit or others. It is understood that an advance to the University hereunder is not a loan to the University and will not require the payment of interest by the University, and that the University acquires no right, title, or interest in or to such advance other than the right to make expenditures therefrom as provided in this clause. The bank of deposit shall act with respect to such account in accordance with any written directions of the Contracting Officer, and

(4) Whenever the University determines that a payment under this clause is justified, pursuant to paragraph (b) of this clause, for the cost of transportation of a spouse or next of kin of an employee who had died or become disabled, a letter request for approval of such payment, itemizing the estimated amount, and setting forth the names of recipients and facts supporting such payments shall be addressed to the Contracting Officer. Applicable procedures outlined in paragraph (b)(2) of this clause shall be followed in the event of any question of fact, approval or disapproval of, and any disagreement relative to, the proposed payment.

(c) The term "employee" as used in this clause shall mean any person who is or has been employed by the University or any subcontractor, or who is or has been engaged as a consultant or borrowed personnel by the University or any subcontractor, and who has become disabled or has died as a result of the special hazards, as referred to in paragraph (b) of this clause, encountered by the University in the conduct of its operation under this contract.

(d) The term "disabled" as used herein shall be deemed to include (1) temporary total disability; (2) temporary partial disability; (3) permanent total disability; and (4) permanent partial disability.

(e) In the event of an accident involving the specified hazards in which any employee shall sustain serious injuries, the University is authorized to pay, subject to the approval of the Contracting Officer, a reasonable amount for the cost of transportation (including hotel, subsistence and other incidental expenses) of the spouse and one or more of next of kin of such injured employee from their respective homes to the place where such injured employee shall be situated and their return therefrom at the conclusion of said visit.

CLAUSE 34 - PRESERVATION OF INDIVIDUAL OCCUPATIONAL RADIATION EXPOSURE RECORDS

Individual occupational radiation exposure records generated in the performance of work under this contract shall be subject to inspection by DOE and shall be preserved by the University until disposal is authorized by DOE, or at the option of the University delivered to DOE upon completion or termination of the contract. Title to such records shall be in DOE.

CLAUSE 35 - PATENT RIGHTS - DOE WEAPONS LABORATORY

(a) Definitions.

(1) "Invention" means any invention or discovery which is or may be patentable or otherwise protectable under Title 35 of the United States Code, or any novel variety of plant which is or may be protected under the Plant Variety Protection Act (7 USC 2321 et seq.).

(2) "Subject invention" means any invention of the University conceived or first actually reduced to practice in the performance of work under this contract, provided that in the case of a variety of plant, the date of determination (as defined in Section 41(d) of the Plant Variety Protection Act, (7 USC 2401(d)) must also occur during the period of contract performance.

(3) "Practical application" means to manufacture, in the case of a composition or product; to practice, in the case of a process or method; or to operate, in the case of a machine or system; and, in each case, under such conditions as to establish that the invention is being utilized and that its benefits are, to the extent permitted by law or Government regulations, available to the public on reasonable terms.

(4) "Made" when used in relation to any invention means the conception or first actual reduction to practice of such invention.

(5) "Small Business Firm" means a small business concern as defined at Section 2 of Public Law 85-536 (15 USC 632) and implementing regulations of the Administrator of the Small Business Administration. For the purpose of this clause, the size standard for small business concerns involved in Government procurement and subcontracting at 13 CFR 121.3-8, and in 13 CFR 121.3-12, respectively, will be used.

(6) "Nonprofit Organization" means a university or other institution of higher education or an organization of the type described in Section 501(c)(3) of the Internal Revenue Code of 1954 (26 USC 501(c)) and exempt from taxation under Section 501(a) of the Internal Revenue Code (26 USC 501(a)) or any nonprofit scientific or educational organization qualified under a State nonprofit organization statute.

(7) "Patent Counsel" means the Department of Energy (DOE) Patent Counsel assisting the DOE contracting activity.

(8) "Exceptional Circumstances" Subject Invention means any subject invention under that heading in the Determinable or the Nonelectable listing of Appendix G or for which DOE otherwise provides the exceptional circumstances finding and analysis in writing under Section 35 USC 202(a)(ii) and the Procedures of 37 CFR Part 401.3(e).

(9) "Weapons Related" Subject Invention means any subject invention occurring under the weapons related programs or the Naval Nuclear Propulsion Program of DOE.

(10) "Electable" Subject Invention means a subject invention occurring under the electable listing of Appendix G or determined by DOE to be electable pursuant to subparagraph (b)(4).

(b) Allocations of Principal Rights.

(1) Assignment to the Government. The University agrees to assign to the Government the entire right, title, and interest throughout the world in and to each subject invention, except to the extent that rights are retained by the University under subparagraph (b)(2) and paragraph (d) below.

(2) Retention by University. Within 2 years after disclosure to DOE, the University may elect in writing to retain title to any subject invention which is not a weapons related subject invention or an exceptional circumstance subject invention. Any subject invention defined to be "electable" in Appendix G, which is hereby incorporated by reference and made a part of this contract, or otherwise determined by DOE to be electable pursuant to subparagraph (b)(4) below is hereby stipulated not to be an exceptional circumstance or weapons related subject invention. Any subject invention defined in Appendix G to be nonelectable is hereby stipulated to be a weapons related or exceptional circumstance subject invention. However, in any case where publication, on sale or public use has initiated the one year statutory period wherein valid patent protection can still be obtained in the United States, the period for election of title may be shortened by the agency to a date that is no more than 60 days prior to the end of the statutory period. The right of the University to elect title to subject inventions is subject to the invention rights disposition in the treaties or international agreements found in Appendix F which is incorporated by reference and made a part of this contract. Where the University elects title in an invention in which DOE has already filed, the University agrees to reimburse patent prosecution costs.

(3) Filing of Applications. The University will file its initial patent application on a subject invention to which it elects to retain title within one year after election of the title or, if earlier, prior to the end of any statutory period wherein valid patent protection can be obtained in the United States after a publication, on sale, or public use, whichever is earlier. The University will file patent applications in additional countries or international patent offices within either 10 months of the corresponding initial patent application or 6 months from the date permission is granted by the Commissioner of Patents and Trademarks to file foreign patent applications where such filing has been prohibited by a Secrecy Order.

(4) Determination of Electability of Subject Inventions. Where status of an invention is determined to be not automatically electable by its listing in Appendix G or is not provided for in Appendix G, the University may request at the time of disclosing such a Subject Invention or within the two year period thereafter specified in subparagraph (b)(2) that DOE make a determination of whether the invention is an exceptional circumstance or weapons related subject invention. When a determination is requested by the University,

DOE will make such a determination on a best efforts basis within 90 days. If DOE is unable to complete its determination within 90 days it will report the status of such determination and will update such status monthly. However, in any case where publication, on sale or public use has initiated the one year statutory period wherein valid patent protection can be sought in the United States, the period for requesting such determination may be shortened by DOE to a date that is not more than 150 days prior to the end of the statutory period. If an invention is not electable the University may request waiver of rights under DOE's regulation patent waiver procedures. DOE shall make a waiver determination within a reasonable time, usually within six months of the waiver request. If DOE is unable to complete its determination within six months it will report the status of such determination and will update such status monthly. The University shall use its best efforts to supply sufficient information to DOE to make its determination.

(5) Government Licenses. With respect to any subject invention in which the University retains title, the Federal Government shall have a nonexclusive, nontransferable, irrevocable, paid-up license to practice or have practiced for or on behalf of the United States the subject invention throughout the world.

(6) Extensions of Time. Requests for extension of time for disclosure, requesting a determination under paragraph (b)(4), election, and filing may at the discretion of DOE, be granted.

(7) International Agreements, Treaties. The DOE reserves the right to unilaterally amend this contract to identify specific treaties or international agreements entered into or to be entered into by the Government after the effective date of this funding agreement and effectuate those license or other rights which are necessary for the Government to meet its obligations to foreign Governments, their nationals and international organizations under such treaties or international agreements with respect to subject inventions made after the date of the amendment.

(8) Biological Materials - Reserved

(c) Minimum Rights Acquired by the Government.

(1) With respect to each subject invention to which the University retains principal or exclusive rights, the University agrees as follows:

(i) The University hereby grants to the Government a nonexclusive, nontransferable, irrevocable, paid-up license to practice or have practiced each subject invention throughout the world by or on behalf of the Government of the United States (including any Government agency).

(ii) The University agrees that with respect to any subject invention in which it has acquired title, the DOE has the right in accordance with the procedures in FAR 27.304-1(g) to require the University, as assignee, or exclusive licensee of a subject invention to grant a nonexclusive, partially exclusive, or exclusive license in any field of use to a responsible applicant or applicants, upon terms that are reasonable under the circumstances, and if the University, assignee, or exclusive licensee refuses such a request, the DOE has the right to grant such a license itself if the DOE determines that--

(A) Such action is necessary because the University or assignee has not taken, or is not expected to take within a reasonable time, effective steps to achieve practical application of the subject invention in such field of use;

(B) Such action is necessary to alleviate health or safety needs which are not reasonably satisfied by the University, assignee, or their licensees;

(C) Such action is necessary to meet requirements for public use specified by Federal regulations and such requirements are not reasonably satisfied by the University, assignee, or licensees; or

(D) Such action is necessary because the agreement required by paragraph (i) of this clause has neither been obtained nor waived or because a licensee of the exclusive right to use or sell any subject invention in the United States is in breach of such agreement.

(iii) The University agrees to convey to DOE upon written request title to any subject invention.

(A) If the University fails to disclose or elect title to the subject invention within the times specified in (b) and (e) or elects not to retain title; provided that DOE may only request title within 60 days after learning of the failure of the University to disclose or elect within the specified times.

(B) In those countries in which the University fails to file patent applications within the times specified in (b)(3) above; provided, however, that if the University has filed a patent application in a country after the times specified in (b)(3) above, but prior to its receipt of the written request of DOE, the University shall continue to retain title in that country.

(C) In any country in which the University decides not to continue the prosecution of any application for, to pay the maintenance fees on, or defend in reexamination or opposition proceeding on, a patent on a subject invention.

(D) The University will notify DOE of any decisions not to continue the prosecution of a patent application, pay maintenance fees, or defend in a reexamination or opposition proceeding on a patent, in any country, not less than 30 days before the expiration of the response period required by the relevant patent office.

(iv) The University agrees to include, within the specification of any United States patent applications and any patent issuing thereon covering a subject invention, the following statement, "This invention was made with Government support under (identify the contract) awarded by the U.S. Department of Energy. The Government has certain rights in the invention".

(v) The University agrees to submit on request periodic reports no more frequently than annually on the utilization of a subject invention or on efforts at obtaining such utilization of a subject invention or on efforts at obtaining such utilization that are being made by the University or its licensees or assignees. Such reports shall include information regarding the status of development, date of first commercial sale or use, gross royalties received by the University, and such other data and information as the agency may reasonably specify. The University also agrees to provide additional reports as may be requested by the agency in connection with any march-in proceedings undertaken by the agency in accordance with subparagraph (c)(1)(ii) above. To the extent data or information supplied under this subparagraph is considered by the University, its licensee, or assignee to be privileged and confidential and is so marked, the agency agrees that, to the extent permitted by law, it will not disclose such information to persons outside the Government.

(vi) The University agrees, when licensing a subject invention, to arrange to avoid royalty charges on acquisitions involving Government funds, including funds derived through a Military Assistance Program of the Government or otherwise derived through the Government, to refund any amounts received as royalty charges on a subject invention in acquisitions for, or on behalf of, the Government, and to provide for such refund in any instrument transferring rights in the invention to any party.

(vii) The University agrees to provide for the Government's paid-up license pursuant to subparagraph (c)(1)(i) above in any instrument transferring rights in a subject invention and to provide for the granting of licenses as required by subparagraph (c)(1)(ii) above, and for the reporting of utilization information as required by subparagraph (c)(1)(v) above, whenever the instrument transfers principal or exclusive rights in a subject invention.

(2) Nothing contained in this paragraph (c) shall be deemed to grant to the Government any rights with respect to any invention other than a subject invention.

(d) Minimum Rights to the University.

(1) The University may reserve upon request a revocable, nonexclusive, royalty-free license in each patent application filed in any country on a subject invention and any resulting patent in which the Government obtains title, unless the University fails to disclose the subject invention within the times specified in subparagraph (e)(2) below. The University's license extends to its domestic subsidiaries and affiliates, if any, within the corporate structure of which the University is a part and includes the right to grant sublicenses of the same scope to the extent the University was legally obligated to do so at the time the contract was awarded. The license is transferable only with the approval of DOE except when transferred to the successor of that part of the University's business to which the invention pertains.

(2) The University's domestic license may be revoked or modified by DOE to the extent necessary to achieve expeditious practical application of the subject invention pursuant to an application for an exclusive license submitted in accordance with applicable provisions in 37 CFR Part 404 and DOE Licensing Regulations. This license will not be revoked in that field of use or the geographical areas in which the University has achieved practical application and continues to make the benefits of the invention reasonably accessible to the public. The license in any foreign country may be revoked or modified at the discretion of the DOE to the extent the University, its licensees, or its domestic subsidiaries or affiliates have failed to achieve practical application in that foreign country.

(3) Before revocation or modification of the license, DOE will furnish the University a written notice of its intention to revoke or modify the license, and the University will be allowed 30 days (or such other time as may be authorized by DOE for good cause shown by the University) after the notice to show cause why the license should not be revoked or modified. The University has the right to appeal, in accordance with the applicable Regulations in 37 CFR

Part 404 and DOE Regulations concerning the licensing of Government-owned inventions, any decision concerning the revocation or modification of its license.

(4) When the Government has the right to receive title, and does not elect to secure a patent in a foreign country, the University may elect to retain such rights in any foreign country in which the University elects to secure a patent, subject to the Government's rights in subparagraph (c)(1) above.

(e) Invention Identification, Disclosures, and Reports.

(1) The University shall establish and maintain active and effective procedures by which the University will use its best efforts to assure that subject inventions are promptly identified and disclosed to University personnel responsible for patent matters within six months of conception and/or first actual reduction to practice, whichever occurs first in the performance of work under this contract. These procedures shall include the maintenance of laboratory notebooks or equivalent records and other records as are reasonably necessary to document the conception and/or the first actual reduction to practice of subject inventions, and records that show that the procedures for identifying and disclosing the inventions are followed. Upon request, the University shall furnish the Contracting Officer a description of such procedures for evaluation and for determination as to their effectiveness.

(2) The University shall disclose each subject invention to the Contracting Officer within two months after the inventor discloses it in writing to University personnel responsible for patent matters or, if earlier, within six months after the University becomes aware that a subject invention has been made, but in any event before any on sale, public use, or publication of such invention known to the University. The disclosure to DOE shall be in the form of a written report and shall identify the contract under which the invention was made, the inventors and for a determinable invention under Appendix G will identify all sources of funding for the invention, and any relationship of the invention to, or use of the invention in DOE's weapons programs or other DOE atomic energy defense activities. It shall be sufficiently complete in technical detail to convey a clear understanding, to the extent known at the time of the disclosure, of the nature, purpose, operation, and physical, chemical, biological, or electrical characteristics of the invention. The disclosure shall also identify any publication, on sale, or public use of the invention and whether a manuscript describing the invention has been submitted for publication and, if so, whether it has been accepted for publication at the time of disclosure. In addition, after disclosure to DOE, the University shall promptly notify DOE of the

acceptance of any manuscript describing the invention for publication or of any on sale or public use planned by the University.

(3) The University shall furnish the Contracting Officer the following:

(i) Interim reports every 12 months (or such longer period as may be specified by the Contracting Officer) from the date of the contract, listing subject inventions during that period, and certifying that all subject inventions have been disclosed (or that there are not such inventions) and that the procedures required by subparagraph (e)(1) above have been followed, and listing all subcontracts containing a patent rights clause or certifying that there were no such subcontracts.

(ii) A final report, within three months after completion of the contracted work, listing all subject inventions or certifying that there were no such inventions.

(4) The University agrees to require, by written agreement, its employees, other than clerical and nontechnical employees, to disclose promptly in writing to personnel identified as responsible for the administration of patent matters and in a format suggested by the University each subject invention made under this contract in order that the University can comply with the disclosure provisions of paragraph (c) above, and to execute all papers necessary to file patent applications on subject inventions and to establish the Government's rights in the subject inventions. This disclosure format should require, as a minimum, the information required by subparagraph (e)(2) above.

(5) The University agrees that the Government may duplicate and disclose subject invention disclosures and all other reports and papers furnished or required to be furnished pursuant to this clause provided, however, that any such disclosure of a subject invention in which the University has elected to retain title is subject to 35 USC 205.

(6) It is recognized that during the course of the work under this contract, the University or its employees may from time to time desire to release or publish information regarding scientific or technical developments conceived or first actually reduced to practice in the course of or under this contract. In order that public disclosure of such information will not adversely affect the patent interests of DOE or the University, patent approval for release or publication shall be secured from Patent Counsel prior to any such release or publication. The Department's response to such requests for approval shall not be withheld for more than 90 days except in circumstances in which a domestic application must be filed in order to protect foreign patent rights. In the

latter case, the Department shall be granted an additional 180 days within which to respond to the request for approval. The period of 180 days may be extended by mutual agreement of the parties.

(f) Examination of Records Relating to Inventions.

(1) The Contracting Officer or any authorized representative shall, until three years after final payment under this contract, have the right to examine any books (including laboratory notebooks), records, and documents of the University relating to the conception or first actual reduction to practice of inventions in the same field of technology as the work under this contract to determine whether--

(i) Any such inventions are subject inventions;

(ii) The University has established and maintains the procedures required by subparagraphs (e)(1) and (4) of this clause; and

(iii) The University and its inventors have complied with the procedures.

(2) If the Contracting Officer learns of an unreported University invention which the Contracting Officer believes may be a subject invention, the University may be required to disclose the invention to DOE for a determination of ownership rights.

(3) Any examination of records under this paragraph will be subject to appropriate conditions to protect the confidentiality of the information involved.

(g) Withholding of Payment.

(1) Any time before final payment under this contract, the Contracting Officer may, in the Government's interest, withhold payment until a reserve not exceeding $50,000 or five percent of the amount of this contract, whichever is less, shall have been set aside if, in the Contracting Officer's opinion, the University fails to--

(i) Establish, maintain, and follow effective procedures for identifying and disclosing subject inventions pursuant to subparagraph (e)(1) above;

(ii) Disclose any subject invention pursuant to subparagraph (e)(2) above;

(iii) Deliver acceptable interim reports pursuant to subparagraph (e)(3)(i) above; or

(iv) Provide the information regarding subcontracts pursuant to subparagraph (h)(4) below.

(2) Such reserve or balance shall be withheld until the Contracting Officer has determined that the University has rectified whatever deficiencies exist and has delivered all reports, disclosures, and other information required by this clause.

(3) Final payment under this contract shall not be made before the University delivers to the Contracting Officer all disclosures of subject inventions required by subparagraph (e)(2) above, and acceptable final report pursuant to subparagraph (e)(3)(ii) above, and all past due confirmatory instruments.

(4) The Contracting Officer may decrease or increase the sums withheld up to the maximum authorized above. No amount shall be withheld under this paragraph while the amount specified by this paragraph is being withheld under other provisions of the contract. The withholding of any amount or the subsequent payment thereof shall not be construed as a waiver of any Government rights.

(h) Subcontracts.

(1) Unless otherwise authorized or directed by the Contracting Officer the University shall include in any subcontract hereunder having as a purpose the conduct of research development or demonstration:

(i) The Patent Rights clause of 37 CFR 401.14 in subcontracts with small businesses or nonprofit organizations except for subcontracts subject to exceptional circumstances; and

(ii) The Patent Rights clause of 41 CFR 9-9.107-5(a) in all other subcontracts.

(2) In the event of a refusal by a prospective subcontractor to accept such a clause the University--

(i) Shall promptly submit a written notice to the Contracting Officer setting forth the subcontractor's reasons for such refusal and other pertinent information that may expedite disposition of the matter; and

(ii) Shall not proceed with such subcontract without the written authorization of the Contracting Officer.

(3) In the case of subcontracts at any tier, DOE, subcontractor, and the University agree that the mutual obligations of the parties created by this clause constitute a contract between the subcontractor and DOE with respect to those matters covered by this clause.

(4) The University shall promptly notify the Contracting Officer in writing upon the award of any subcontract at any tier containing a patent rights clause by identifying the subcontractor, the applicable patent rights clause, the work to be performed under the

subcontract, and the dates of award and estimated completion. Upon request of the Contracting Officer, the University shall furnish a copy of such subcontract, and, no more frequently than annually, a listing of the subcontracts that have been awarded.

(i) Preference for United States Industry.

Unless provided otherwise, where the University receives title to any subject invention, neither the University nor any assignee of the University shall grant to any person the exclusive right to use or sell any subject invention in the United States unless such person agrees that any products embodying the subject invention will be manufactured substantially in the United States. However, in individual cases, the requirement may be waived by DOE upon a showing by the University or assignee that reasonable but unsuccessful efforts have been made to grant licenses on similar terms to potential licensees that would be likely to manufacture substantially in the United States or that under the circumstances domestic manufacture is not commercially feasible.

(j) Reserved.

(k) Atomic Energy.

(1) No claim for pecuniary award or compensation under the provisions of the Atomic Energy Act of 1954, as amended, shall be asserted by the University or its employees with respect to any invention or discovery made or conceived in the course of or under this contract.

(2) Except as otherwise authorized in writing by the Contracting Officer, the University will obtain patent agreements to effectuate the provisions of subparagraph (k)(1) of this clause from all persons who perform any part of the work under this contract, except nontechnical personnel, such as clerical employees and manual laborers.

(l) Facilities License.

In addition to the rights of the parties with respect to inventions or discoveries conceived or first actually reduced to practice in the course of or under this contract, the University agrees to and does hereby grant to the Government an irrevocable, nonexclusive, paid-up license in and to any inventions or discoveries regardless of when conceived or actually reduced to practice or acquired by the University, which are owned or controlled by the University, at any time through completion of this contract and which are incorporated or embodied in the construction of the facility or which are utilized in the operation of the facility or which cover articles, materials, or products manufactured at the facility: (1) to practice or to have practiced by or for the Government at the facility, and (2) to transfer such license with the transfer of that facility. The acceptance or exercise by the Government of the aforesaid rights and license shall not prevent the Government at any time from contesting the enforceability, validity or scope of, or title to, any rights or patents herein licensed.

(m) Patent Functions.

For those inventions in which the University receives title either by election or waiver of Government rights, the University will normally be expected to prepare and prosecute patent applications at private expense.

(n) Rights Governed by Other Agreements.

Rights to inventions made under agreements other than funding agreements with third parties shall be governed by the appropriate provisions incorporated, with DOE approval, in such agreements, notwithstanding any disposition of rights contained in this Prime Contract. Disposition of rights under any such agreement shall be in accordance with any DOE class waiver (including Work for Others and User class waivers) or individually negotiated waiver which applies to the agreement and shall take precedence over any disposition of rights in this Prime Contract. Where an invention is conceived in the course of work under this Prime Contract, but is later reduced to practice under a Work for Others agreement, rights to such invention shall be governed by the provisions incorporated, with DOE approval, in the Work for Others agreement. Nothing in this paragraph shall abrogate the rights of third parties under agreement approved by DOE and entered into prior to any such DOE class waiver.

(o) Transfer of Patent Rights to a Successor Contractor. Reserved

(p) Costs.

Except as otherwise specified in this paragraph, no costs are allowable as direct or indirect costs for the preparation, filing or prosecution of patent applications or the payment of maintenance fees or licensing and marketing costs where the University elects to retain title.

(q) Assignments/Licensees.

(1) The University agrees that rights to a subject invention in the United States may not be assigned without the approval of DOE, except where such assignment is made to an organization which has as one of its primary functions the management of inventions, provided that such assignee will be subject to the same provisions as the University.

(2) The University agrees that it will make efforts that are reasonable under the circumstances to attract licensees of subject inventions that are small business firms and that it will give a preference to a small business firm when licensing a subject invention if the University determines that the small business firm has a plan or proposal for marketing the invention which, if executed, is equally as likely to bring the invention to practical application as any

plans or proposals from applicants that are not small business firms; provided, that the University is also satisfied that the small business firm has the capability and resources to carry out its plan or proposal. The decision whether to give a preference in any specific case will be at the discretion of the University. However, the University agrees that DOE may review the University's licensing program and decisions regarding small business applicants, and the University will negotiate changes to its licensing policies, procedures, or practices with DOE when the review discloses that the University could take reasonable steps to implement more effectively the requirements of this subparagraph (q)(2).

(r) Royalty Uses and Shares.

(1) After payment of patenting costs, licensing costs, payments to inventors, and other expenses incidental to the administration of subject inventions, the balance of any royalties or income earned and retained by the University during any fiscal year on subject inventions under this or any successor contract containing the same requirement, up to any amount equal to five percent of the budget of the Laboratory for that fiscal year, shall be used by the University for scientific research, development, and education consistent with the research and development mission and objectives of the Laboratory, including activities that increase the licensing potential of other inventions of the Laboratory. If the balance exceeds five percent, 75 percent of the excess above five percent shall be paid by the University to the Treasury of the United States and the remaining 25 percent shall be used by the University only for the same purposes as described above. To the extent it provides the most effective technology transfer, the licensing of subject inventions shall be administered by University employees on location at the Laboratory.

(2) The University, as a demonstration of its commitment to the National technology transfer objective, agrees to return net royalties derived from the licensing of intellectual property to the Laboratory.

(3) Royalties or other income received by the University which are required to be used at the Laboratory pursuant to subparagraph (r)(1) of this clause shall be used for scientific research, development, and educational purposes. Any inventions arising out of such use at the Laboratory will be deemed "subject inventions" under the contract.

The University shall include as a part of its annual Laboratory Institutional Plan or other annual document a plan setting out those uses to which such royalty funds will be applied at the Laboratory and, at the end of the year, a separate accounting for how the funds were actually used. Such uses shall be consistent with the mission and objectives of the Laboratory and shall be subject to DOE review. The funds may be utilized to support cooperative ventures between the University and DOE under the authority of Section 646(a) of the DOE Organization Act and may also be utilized to supplement the Laboratory Director's discretionary funds. However, under no circumstances shall the royalties be used for the augmentation of general DOE program funds. The University's use of the royalties shall be evaluated as part of the annual appraisal process.

In the event of termination or expiration of this contract, any unexpended balance of net royalties received for use at the Laboratory shall be transferred, at DOE's request to a successor Contractor, or in the absence of a successor Contractor, to such other entity designated by DOE. Should the University no longer operate the Laboratory, the University will transfer title as one package in all patents and patent applications, licenses and rights thereunder which arose at the facility to the successor contractor or Government if the successor contractor or Government agrees to honor all license terms, obligations to inventors, and obligations and liabilities of the University in connection with those patents and patent applications. If the successor contractor or Government refuses to fully honor the foregoing, then the University shall continue with title in the University.

(4) For inventions in which the University takes sole title, the University shall establish a policy for the sharing of royalties with inventors including Federal employee co-inventors when DOE determines it appropriate.

(5) Whenever any annual invention awards or annual royalty payments to an inventor exceeds 10 percent of the inventor's annual base salary, the University shall identify all such inventors to the Contracting Officer.

(s) Conflicts of Interest.

Under the terms of this Agreement, the University is authorized to elect to acquire title to certain inventions and, by such elections as well as waivers granted by the Government, has the right to earn royalties for inventions derived from the work hereunder. The University has also proposed and agreed to pay all of the net proceeds of such royalties into a fund to be utilized for further work under this contract under terms and conditions set forth herein.

The parties agree that although such receipt and use of royalties as an appropriate activity hereunder, it is the mutual desire of the parties to assure that the appearance of conflict of interest or questions concerning organizational objectivity are carefully avoided in every aspect of contract work.

To that end, the University has established and implemented a system based upon the California Fair Political Practices Act and University policy which addresses potential conflicts of interest for individual employees in the conduct of research and development activities in which they could have financial interest. A copy of this system will be furnished to the Contracting Officer and shall be maintained on a current basis during the life of the contract.

The University shall also develop and implement a system to assure that in the performance of the work under this contract the University shall address the appearance of conflict of interest by any of its employees in the area in which the University may have a financial interest arising out of the royalty provisions hereof. Such system shall appropriately address the several unique technology transfer aspects of the relationships encountered under this contract including:

(1) Potential interference with ongoing DOE projects and programs including:

    (i) The use of facility and work for others

    (ii) Non-government funded work

    (iii) The commercialization of University developed inventions

(2) The proper notification of the Department as to any licensing of or assignments to other organizational units of the University, and any action taken by the University under these procedures.

(3) The method by which sponsors of work to be performed hereunder, including the Department, shall be made aware of relevant rights acquired by the University hereunder.

Such procedures shall be submitted to the Contracting Officer for approval.

(t) Liability of the Government.

The University shall include in all license agreements and in any assignment the following clause unless otherwise approved or directed by the Contracting Officer following consultation with DOE Patent Counsel:

> "The U.S. Government is neither a party to nor assumes any liability for activities of the University of California in connection with this license."

Further, the University shall not include in any license agreement or assignment any guarantee or requirement which would obligate the Government to pay any costs or create any liability on behalf of the Government.

(u) Educational Awards Subject to 35 USC 212.

The University shall notify the Contracting Officer prior to the placement of any person subject to 35 USC 212 in an area of technology related to Exceptional Circumstances technology, or which is subject to treaties or international agreements as set forth in subparagraphs (b)(2), (b)(4) and (b)(7) of this clause or agreements other than funding agreements. The Contracting Officer shall have the right to disapprove such placement.

(v) Waiver Requested Inventions.

It is agreed that the University may elect to retain title to subject inventions listed in Appendix H which is incorporated by reference and made a part of this contract.

CLAUSE 36 - PATENT INDEMNITY

Except as otherwise authorized by the Contracting Officer, the University shall obtain indemnification of the Government and its officers, agents, and employees against liability, including costs, for infringement of U.S. Letters Patent (except U. S. Letters Patent issued upon an application which is now or may hereafter be kept secret or otherwise withheld from issue by order of the Government) from the University's subcontractors in accordance with 48 CFR 27.203.

CLAUSE 37 - AUTHORIZATION AND CONSENT

The Government hereby gives its authorization and consent for all use and manufacture of any invention described in and covered by a patent of the United States in the performance of this contract or any part hereof or any amendment hereto or any subcontracts hereunder (including all lower-tier subcontracts).

In the case of suit or potential of suit in copyright infringement, the University may request authorization and consent in copyright from DOE. Programmatic necessity shall be a major consideration in grant of authorization and consent.

CLAUSE 38 - NOTICE AND ASSISTANCE REGARDING PATENT AND COPYRIGHT INFRINGEMENT (DEVIATION)

(a) The University shall report to the Contracting Officer, promptly and in reasonable written detail, each notice or claim of patent or copyright infringement based on the performance of this contract of which the University has knowledge.

(b) In the event of any claim or suit against the Government on account of any alleged patent or copyright infringement arising out of the performance of this contract or out of the use of any supplies furnished or work or services performed hereunder, the University shall furnish to the Government when requested by the Contracting Officer, all evidence and information in possession of the University pertaining to such suit or

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Supplemental Agreement to
Contract No. W-7405-ENG-36

CLAUSE 68 - TECHNOLOGY TRANSFER

The parties agree that technology transfer activities arising out of the work performed under this contract, and consistent with applicable laws and regulations, including executive orders, are legitimate functions of the Laboratory and will be conducted as mutually agreed to by the parties.

IN WITNESS HEREOF The parties hereto have executed this Supplemental Agreement as of the day and year first above written.

THE UNITED STATES OF AMERICA DEPARTMENT OF ENERGY

DATE: ___________

BY: ______________________
R. G. Romatowski, Manager
Albuquerque Operations Office
Contracting Officer

THE REGENTS OF THE UNIVERSITY
OF CALIFORNIA

DATE: ___________ BY: ______________________

TITLE: ______________________

DATE: ___________ BY: ______________________

APPROVED AS TO FORM: TITLE: SECRETARY

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GLENN R. WOODS

Modification No. 286
Supplemental Agreement to
Contract No. W-7405-ENG-36

APPENDIX F

Treaties or International Agreements

The following attached documents entitled:

1. Current Energy R&D Bilateral Agreements as of July 1987
2. Nuclear Energy Agency (NEA) Agreements with U.S. Department of Energy Involvement
3. Summary Table of Collaborative Projects in Energy Research, Development, and Demonstration

are made a part of this Appendix F and contain a listing of international agreements which may impact invention rights of the University as stipulated in Clause No. 35 Patent Rights, Paragraph (b).

CURRENT ENERGY R&D BILATERAL AGREEMENTS AS OF JULY 1987 WITH UNITED STATES DEPARTMENT OF ENERGY INVOLVEMENT
in the field of

BASIC ENERGY SCIENCES

Country	Start Date End Date	Type of Agreement	Description
1. Israel	05/1987 05/1992	Umbrella	Cooperative activities between DOE and MOSD in areas such as high energy physics; nuclear physics; applied mathematical sciences; magnetic fusion; engineering research; material sciences/chemical sciences; earth sciences; and health and environmental sciences.

CURRENT ENERGY R&D BILATERAL AGREEMENTS AS OF JULY 1987 WITH UNITED STATES DEPARTMENT OF ENERGY INVOLVEMENT in the field of

SCIENCE AND TECHNOLOGY (S&T)

Country	Start Date End Date	Type of Agreement	Description
1. Japan	05/1980 10/1987	Umbrella BEING RENEGOTIATED	Develop cooperative activities in scientific and technological R&D in such fields as may be mutually agreed for peaceful purposes.
2. Japan	04/1984 04/1989	Project (under 1 above)	Promote research on electric field effects including biological and behavioral effects, if any, on non-human primates, resulting from electric-fields associated with the transmission of high voltage electricity.
3. Spain	12/1985 none	Umbrella	Establish responsibilities, guidelines and procedures for evaluating, funding and coordinating research proposals, projects and related activities in the field of energy selected and funded by the US-Spain Joint Committee for S&T Cooperation.

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CURRENT ENERGY R&D BILATERAL AGREEMENTS AS OF JULY 1987 WITH UNITED STATES DEPARTMENT OF ENERGY INVOLVEMENT in the field of

HIGH ENERGY PHYSICS (HEP)

Country	Start Date End Date	Type of Agreement	Description
1. China	01/1979 01/1989	Umbrella	Establish a framework for cooperation in high energy physics including theoretical and experimental research, accelerator design and construction techniques.
2. Japan	11/1979 05/1989	Project (under 5 "R&D")	Establish a framework for cooperation in the field of high energy physics, including research; accelerator and detector instrumentation R&D; the fabrication and subsequent use of new experimental devices and facilities.
3. Spain	10/1986 none	Project	Providing additional funding for electron-positron collision interactions.
4. Spain	10/1986 10/1989	Project (under 3 "S&T")	Objective is to study nuclear dynamics by performing experiments involving pion scattering and to develop models of the nucleas using quark degrees of freedom.
USSR		(under 8 "R&D")	

CURRENT ENERGY R&D BILATERAL AGREEMENTS AS OF JULY 1987 WITH UNITED STATES DEPARTMENT OF ENERGY INVOLVEMENT in the field of

CONSERVATION

Country	Start Date End Date	Type of Agreement	Description
1. S.Korea	11/1981 11/1991	Umbrella	Promoting cooperation in the broad areas of energy conservation through exchange of information, personnel, small item purchases. (DOE/ANL)

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CURRENT ENERGY R&D BILATERAL AGREEMENTS AS OF JULY 1987 WITH UNITED STATES DEPARTMENT OF ENERGY INVOLVEMENT in the field of

ENERGY RESEARCH AND DEVELOPMENT (R&D)

Country	Start Date End Date	Type of Agreement	Description
1. Canada	12/1986 12/1996	Umbrella	Establishing wider cooperation in the areas of R&D.
2. Finland	11/1980 11/1990	Umbrella	Establishing wider cooperation in the areas of R&D.
3. Israel	06/1984 06/1989	Umbrella	Establishing wider cooperation in the areas of R&D.
4. Italy	12/1985 12/1990	Umbrella	Establishing wider cooperation in the areas of R&D.
5. Japan	05/1979 05/1989	Umbrella	Maintain and intensify cooperation in R&D in energy and related fields.
6. Spain	06/1986 06/1991	Umbrella	Establishing wider cooperation in the areas of R&D.
7. UK	10/1984 10/1989	Umbrella	Establishing wider cooperation in the areas of R&D.
8. USSR	06/1983 06/1988	Umbrella	Permits the exchanges of information, personnel and equipment in the field of peaceful uses of atomic energy.
9. Venezuela	06/1980 06/1998	Umbrella	Establishing wider cooperation in the areas of R&D.

CURRENT ENERGY R&D BILATERAL AGREEMENTS AS OF JULY 1987 WITH UNITED STATES DEPARTMENT OF ENERGY INVOLVEMENT in the field of

FOSSIL ENERGY

Country	Start Date End Date	Type of Agreement	Description
1. Brazil	05/1984 none	Umbrella	Feasibility of a suitable site with a 4 meter seam of 55% ash coal near Porto Alegre, Rio Grande do Sul.
2. Brazil	01/1985 01/1990	Project (under 1 above)	Development of technology for a coal gasification project utilizing the site at Triunfo in Rio Grande do Sul to produce synthetic gas and other fuels to assist in achieving the goal of oil import substitution.
3. Canada	06/1979 06/1989	Umbrella	Establish framework for cooperation with R&D activities in tar sands and heavy oil extraction processing and related technologies.
4. Canada	06/1979 12/1989	Project (under 3 above)	Assemble, coordinate and intrepret existing knowledge of resources and characterization of each deposit; develop comprehensive data on the nature of major tar sand (oil sand) deposits; develop a tar sand resource and deposit characteristics database.
5. Canada	09/1982 12/1989	Project (under 3 above)	Coordinate laboratory experiments to evaluate in-situ steam processes enhanced by additives.
6. Canada	09/1982 09/1989	Project (under 3 above)	Provide guidelines for the dissemination of information on tar sands and heavy oil.
7. Canada	02/1986 12/1987	Project (under 3 above)	Conduct programs of experimentation to evaluate selected geophysical techniques for determining spatial shape and location of thermal fronts in steam flooding, in-situ combustion, and in-situ steam processes enhanced by various additives for oil recovery from tar sands and heavy oils.

in the field of Fossil Energy

Country	Start Date End Date	Type of Agreement	Description
8. China	04/1985 04/1990	Umbrella	Cooperate in the field of fossil energy with emphasis on atmospheric and pressurized fluid-bed combustion; surface coal gasification; direct and indirect coal liquefaction, enhanced oil recovery, etc.
9. Israel	10/1984 10/1987	Project (under 3 "R&D")	Explore intra- and extra-particle chemistry, mass transfer and energy transfer during conversion of US eastern high sulfur bituminous coal in a split-stage fluidized-bed reactor of innovative design.
10. Israel	10/1984 10/1987	Project (under 3 "R&D")	Study of the interaction effects of shale matrix and kerogen chemical composition using shale property variations found in Israel but not in the US. The research will investigate ways to remove chemically-bound sulfur from both US and Israeli oil shales.
11. Israel	10/1984 10/1987	Project (under 3 "R&D")	Conduct research at Israel's Soreq nuclear facility using electronic image processing to study the way cracks form within shale rock.
12. Israel	10/1984 10/1987	Project (under 3 "R&D")	Investigate capabilities to separate oily, organic matter from shale to produce shale oil.
13. Italy	04/1986 12/1988	Project (under 4 "R&D")	Cooperation in carrying out a bench-scale research program for the conversion of coal to liquid hydrocarbons.
14. Japan	05/1986 05/1989	Project (under 5 "R&D")	Establish comprehensive cooperation in the area of coal reserach R&D in order to accelerate the development of coal energy R&D efforts on the basis of reciprocity and mutual benefit.

in the field of Fossil Energy

Country	Start Date End Date	Type of Agreement	Description
15. Mexico	06/1983 06/1988	Umbrella	Exchange scientific and technological information regarding petroleum research and development. Establish and develop basic and applied research programs.
16. Norway	04/1987 04/1992	Umbrella	Establish an exchange of scientific and technological information regarding fossil energy R&D and conduct joint basic and/or applied fossil energy research projects (EOR).
17. S.Korea	11/1981 11/1991	Umbrella	Exchange of coal related information, laboratory staff and technical consultations in coal utilization technologies. (DOE/PETC)
18. Spain	06/1986 06/1991	Project (under 6 "R&D")	Cooperate in the R&D of coal gasification and geothermal energy technologies.
19. UK	07/1974 none	Umbrella	Exchange of information under an agreement between US Dept of Interior and UK National Coal Board (this exchange included DOE's predecessor agency, ERDA, under the Energy Reorganization Act of 1974) in all areas of the utilization of coal from resource identification to end-use.
20. UK	09/1986 09/1991	Project (under 7 "R&D")	Research in discrepancy analysis of enhanced oil recovery by inventory of reservoir models, selection of EOR projects, exchange and analysis of information, reservoir simulation, etc
21. Venezuela	07/1980 03/1988	Project (under 9 "R&D")	Exchange published technical information and jointly modify or develop new techniques for the characterization of heavy crude oil and heavy ends.

in the field of Fossil Energy

Country	Start Date End Date	Type of Agreement	Description
22. Venezuela	07/1980 03/1988	Project (under 9 "R&D")	Cooperate in university, energy technology center and national laboratory research programs in enhanced oil recovery techniques.
23. Venezuela	07/1980 03/1990	Project (under 9 "R&D")	Develop a consistent and comprehensive database on the performance of enhanced oil recovery projects.
24. Venezuela	09/1980 09/1988	Project (under 9 "R&D")	Develop or increase the efficiency of specific enhancd oil recovery thermal processes.
25. Venezuela	02/1982 03/1988	Project (under 9 "R&D")	Cooperate in coal technologies at universities, energy technology centers and national laboratories.
26. Venezuela	07/1983 02/1988	Project (under 9 "R&D")	Cooperate in improvement of modeling capability to predict occurance of cracks produced by subsidence due to fluid withdrawal and/or removal of subsurface material.
27. Venezuela	03/1984 03/1988	Project (under 9 "R&D")	Training of Venezuelan petroleum engineers at Elks Hills Naval Petroleum Facility.

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CURRENT ENERGY R&D BILATERAL AGREEMENTS AS OF JULY 1987
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in the field of

NUCLEAR ENERGY

Country	Start Date End Date	Type of Agreement	Description
1. Australia	04/1987 12/1987	Project	DOE to provide on reimbursable basis, aerial radiological survey over area of land situated in the State of South Australia using high resolution detection equipment and on-board computerized specloroscope analysis to locate area of residual contamination.
2. France	01/1977 12/1987	Umbrella	Establish for mutual benefit a balanced exchange of LMFBR technology, i.e., safety to include experimental out-of-pile and in-pile research and theoretical analyses; and physics including nuclear data, calculation methods, etc.
3. France	10/1981 10/1986	Project BEING RENEGOTIATED	Developing reduced enrichment research reactor fuels.
4. France	04/1983 04/1988	Umbrella	Cooperation on research, development, test and evaluation to improve physical protection of nuclear materials and facilities.
5. France	09/1985 09/1990	Umbrella	Establish basis for cooperation in the field of remote systems technology, i.e., applications feasibility; remote work efficiency; optimization and refinement.
6. FRG	06/1976 12/1987	Umbrella	Finding solutions to mutually agreed upon problems connected with the design, development, construction and operation of nuclear power systems utilizing LMFBRs and to exchange information developed during the resolution of these problems.

in the field of Nuclear Energy

Country	Start Date End Date	Type of Agreement	Description
7. FRG	02/1977 02/1992	Umbrella	Development of gas-cooled reactors in view of their possible application as high temperature gas-cooled reactors for steam cycle, direct cycle or process heat, or possibly as gas-cooled fast breeder reactors. NOTE: Switzerland is an active participant with France being inactive participant.
8. FRG	09/1977 09/1987	Letters	Research and development activities to improve nuclear material safeguards and physical security.
9. FRG	04/1987 04/1992	Project	Establish basis for cooperation in the field of remote systems technology in areas such as remote connector evaluations, low-flow ventilation system (off-gas technology), robotic process samples and advanced servomanipulator hardware.
10. Japan	01/1979 01/1989	Umbrella	Cooperation shall be directed towards finding solutions to mutually agreed problems associated with the design, development, construction and operation of nuclear power systems utilizing LMFBRs.
11. Japan	09/1983 01/1989	Project (under 10 above)	To develop intensive and long-term cooperation between Clinch River Breeder Reactor and MONJU projects; specifically overall plant design, component and systems engineering, fuels, materials, seismic, probabilistic risk assessment, construction techniques, etc.

Country	Start Date End Date	Type of Agreement	Description
12. Japan	01/1984 01/1988	Project (under 10 above)	To identify and establish agreement on the key safety issues relevant to the licensing of LMFBRs; to develop where possible an agreed common approach to these key safety issues; and to produce, to the extent possible, common safety design principles and criteria by using the above agreed common safety design principles and criteria by using the above agreed common approach.
13. Japan	04/1984 05/1989	Umbrella	Review jointly the impact of the Three Mile Island accident on reactor plant facilities, evaluate and investigate emergency counter-measures and reactor behavior, and develop industrial technologies with respect to radioactive decontamination and waste treatment.
14. Japan	01/1985 01/1989	Project (under 10 above)	Provide for cooperative joint program for the compilation of a centralized reliability database for LMFBR components.
15. Japan	03/1985 03/1990	Project (under 10 above)	To demonstrate the ability of the liquid-fed ceramic melter to vitrify civilian high level waste from the nuclear power fuel cycle through an experimental program.
16. Japan	09/1985 09/1990	Umbrella	Establishes the basis for the exchange of information and personnel, and testing of equipment in each other's facilities, related to developing the technology for high temperature gas-cooled reactors.
17. Japan	09/1985 09/1988	Project (under 10 above)	Japan is conducting experiments at Tower Shielding Facility at Oak Ridge National Laboratory to study properties of various materials and configurations to neutron radiation and other associated effects in fast reactors.

Country	Start Date End Date	Type of Agreement	Description
18. Japan	11/1985 03/1992	Project (under 10 above)	A two part collaborative program wherein long-life Core Systems are jointly developed and tested in the Fast Flux Test Facility and improved fuel fabrication specifications are developed.
19. Japan	11/1986 11/1988	Project (under 10 above)	Conduct a joint program of experimental research on advanced core designs for liquid metal fast spectrum reactors using the Zero Power Plutonium Reactor (ZPPR) critical facility located at ANL, Idaho.
20. Japan	05/1987 09/1990	Project (under 15 above)	Each Party to supplement its metals database through the exchange of needed metals property data. Specific activities shall include the exchange of test specimens, incorporation of them in ongoing or planned testing programs and exchange results.
21. Japan	05/1987 09/1990	Project (under 15 above)	Each Party to supplement its graphite materials database through the exchange of needed graphite property data. Specific activities shall include exchange of test specimens, incorporation of them in ongoing or planned testing programs and exchange of the test results.
22. Spain	12/1985 12/1988	Project (under 3 "S&T")	Exchange of information and personnel in the area of probabilitics risk assessments for light water reactors.
23. Switzerland	11/1982 11/1990	Project	Compare the behavior of DOE pellet-type and EIR (Swiss) particulate-type mixed carbide fuels under irradiation in the Fast Flux Test Facility.
24. UK	09/1976 12/1987	Umbrella	A reasonably balanced exchange of LMFBR technology in such areas as: reactor safety, reactor neutronics analysis and experimentation, etc.

in the field of Nuclear Energy

Country	Start Date End Date	Type of Agreement	Description
25. UK	05/1979 12/1988	Project (under 24 above)	Establish and carry out a joint experimental and analytical program to investigate the neutronic and irradiation performance of higher actinides in fast spectrum reactors.
26. UK	11/1979 11/1987	Project (under 24 above)	Establish and carry out a joint experimental and analytical program to investigate the behavior of fuel pins under reactor core loss of cooling and/or transient over-power accident conditions and to assist reactor designers in the prediction of the behavior of a reactor core and its fuel under hypothetical accident conditions.
27. UK	02/1980 12/1988	Project (under 24 above)	Establish and carry out a joint experimental and analytical program to investigate "in-reactor" swelling and creep behavior of current and potential future DOE and UKAEA fuel cladding in fast breeder reactors.
28. UK	02/1980 12/1988	Project (under 24 above)	Establish and carry out a joint experimental and analytical program to investigate the behavior under irradiation of LMFBR fuels and cladding materials.
29. UK	11/1982 12/1987	Project (under 24 above)	Establish agreement, develop a common approach and assemble and/or develop compatible information in support of safety cases for licensing future fast reacteors in the US and UK.
30. UK	05/1983 05/1988	Project (under 24 above)	Establish and carry out a joint experimental and analytical program to investigate the performance of a 252 Californium (cf) 'Shuffler' system for the measurement of residual fuel in LMFBR head-end waste arisings.
31. UK	03/1985 03/1989	Umbrella	Establish a reciprocal and balanced exchange of decommissioning technology and experience with nuclear facilities.

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in the field of Nuclear Energy page 6

Country	Start Date End Date	Type of Agreement	Description
32. UK	12/1985 12/1990	Project (under 24 above)	Joint experimental and analytical program to investigate the performance of fibre-optic coupled spectrophotometry for the measurement of fissile material concentrations.

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CURRENT ENERGY R&D BILATERAL AGREEMENTS AS OF JULY 1987 WITH UNITED STATES DEPARTMENT OF ENERGY INVOLVEMENT in the field of

INFORMATION EXCHANGE AND/OR PERSONNEL EXCHANGE

Country	Start Date End Date	Type of Agreement	Description
1. Canada	09/1982 06/1989	Project (under 3 FOSSIL)	Provide guidelines for the dissemination of information on tar sands and heavy oil.
2. Canada	12/1986 12/1996	Project (under 1 "R&D")	Objective is to implement collaboration in R&D activities pertaining to energy technologies.
3. France	06/1982 06/1987	Project BEING RESIGNED	Exchange of information as to the existence and availability of energy-related literature.
4. FRG	11/1981 06/1987	Project BEING RESIGNED	Exchange of information as to the existence and availability of energy-related literature.
5. Israel	10/1984 10/1989	Project (under 3 "R&D")	For the exchange of information and personnel.
6. Israel	06/1985 06/1990	Project (under 3 "R&D")	Establish a reasonably balanced exchange of information with emphasis on comprehensive coverage of national literature rather than exact quid pro quo.
7. Israel	05/1987 05/1992	Project (under 1 "ER")	Exchange of information and personnel between DOE and MOSD under the Basic Energy Sciences Umbrella.
8. Italy	09/1986 09/1988	Project (under 4 "R&D")	Establish for the mutual benefit of the Parties, a reasonably balanced exchange of energy information.
9. Netherlands	06/1982 06/1992	Project	Exchange of information as to the existence and availability of energy-related literature.

in the field of Information and/or Personnel Exchange page 2

Country	Start Date End Date	Type of Agreement	Description
10. Nordic Countries (Sweden, Norway, Finland, Denmark)	07/1981 06/1987	Project BEING RESIGNED	Exchange of information as to the existence and availability of energy-related literature.
11. UK	05/1985 05/1990	Project (under 7 "R&D")	Exchange of information as to the existence and availability of energy-related literature.

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in the field of

RADIOACTIVE WASTE MANAGEMENT (RW)

Country	Start Date End Date	Type of Agreement	Description
1. Belgium	01/1981 01/1989	Umbrella	Establish a reasonably balanced exchange of technology in the field of radioactive waste management to include terminal storage in geological formations; technology of retrievable storage; waste processing technology and environmental effects.
2. Canada	08/1982 08/1992	Umbrella	Study of mutually agreed topics associated with the management of radioactive waste and related activities of the nuclear fuel cycle, i.e., preparation and packaging, decontamination and decommissioning; surface and subsurface storage, etc.
3. Canada	03/1986 03/1989	Project (under 2 above)	Carry out a joint experimental and analytical research projects on the characterization of geologic formations at the underground research laboratory in Manitoba and other research areas mutually agreed upon.
4. EC	10/1982 10/1987	Umbrella BEING EXTENDED	Establish a reasonably balanced exchange of information in the management of radioactive wastes, i.e., characterization of waste forms and disposal in geologic formations.
5. France	07/1983 07/1988	Umbrella	Establish the basis for cooperation in the field of radioactive waste management of the nuclear fuel cycle, i.e., preparation and packaging; decontamination and decommissioning; surface and subsurface storage; characterization of geologic formations; disposal of geologic formations; transportation requirements.

in the field of Radioactive Waste Management

Country	Start Date End Date	Type of Agreement	Description
6. France	10/1983 none	Project (under 5 above)	Cooperate in the areas of treatment of radioactive waste and decontamination and decommissioning activities throughout the course of the DOE Demonstration Project at the Western New York Nuclear Service Center located at West Valley, New York.
7. France	06/1986 none	Project (under 5 above)	Confirm intent to expand radioactive waste management cooperation in the area of surface and subsurface disposal and storage of low-level radioactive waste, as well as defined activities.
8. FRG	12/1974 12/1989	Umbrella	Cooperation in radioactive waste management with regard to alternatives of disposal of separated waste products and disposal of spent fuel including but not limited to decontamination and decommissioning; surface storage; transportation requirements; public acceptance issues, etc.
9. FRG	10/1981 10/1991	Project (under 8 above)	Obtain and analyze data on: the migration of brine under the influence of heat and radiation; the suitability of test procedures and performance of test equipment; the performance of materials suitable for packaging radioactive wastes under the influence of heat radiation and brine; and temperature and stress fields associated with mining of cavities in salt and with emplacement of heat sources in salt.
10. FRG	11/1984 11/1990	Project (under 8 above)	Undertake a joint experimental and analytical program for the development of processes for the treatment and immobilization of high-level radioactive waste and to use these processes ofr the fabrication of isotopic sources of radiation and heat (isotopic heat sources).

in the field of Radioactive Waste Management

Country	Start Date End Date	Type of Agreement	Description
11. Japan	12/1986 12/1996	Umbrella	Study topics and develop cooperatively and jointly technology and techniques necessary for the safe management of radioactive wastes.
12. UK	10/1986 10/1991	Umbrella	Exchange of technology for management of radioactive wastes in cooperative fields as preparation/packaging; surface/subsurface storage; field/laboratory testing; environment and safety issues; public acceptance, etc.
13. Sweden	09/1980 12/1990	Umbrella	Maintain a reasonably balanced exchange of information in the area of management of radioactive wastes; to engage in cooperative programs for field testing experiments and techniques related to measuring the performance characteristics of granitic rock system, utilizing the Stripa mine, in order to assess the suitability of such rock types for terminal storage of radioactive material.
14.Switzerland	04/1985 04/1990	Umbrella	Study of mutually agreed topics associated with the management of radioactive waste and related activities of the nuclear fuel cycle.
15.Switzerland	06/1987 06/1990	Project (under 14 above)	Provide framework for collaboration on a technical project concerning modelling of flow and transport through fractured rock in general, and the interpretation and modelling of field data required for assessment of potential geologic waste disposal facilities.

CURRENT ENERGY R&D BILATERAL AGREEMENTS AS OF JULY 1987
WITH THE UNITED STATES DEPARTMENT OF ENERGY INVOLVEMENT
in the field of

MAGNETIC FUSION ENERGY (MFE)

Country	Start Date End Date	Type of Agreement	Description
1. China	05/1983 05/1988	Umbrella	Cooperate in promoting each other's program in Nuclear Physics and Controlled Magnetic Fusion.
2. China	03/1986 05/1988	Project (under 1 above)	Intellectual property rights for agreement in Nuclear Physics and Controlled Magnetic Fusion.
3. EC	12/1987 12/1996	Umbrella	Maintain and intensify cooperation between EURATOM and DOE in the areas covered by their respective magnetic fusion programs in order to develop the scientific understanding and technological underlying a magnetic fusion power system.
4. EC	05/1987 12/1991	Project (under 3 above)	Investigate influence of pellet injection on long-pulse ohmic and additionally, i.e., auxiliary, heated plasmas in the JET device over two operational periods between major shutdowns for the mutual benefit of both Parties.
5. EC	05/1987 05/1992	Project (under 3 above)	Investigate technical areas on Tore Supra in order to advance scientific understanding of magnetic confinement of fusion plasmas for use in future research and development.
6. Japan	08/1979 08/1988	Project (under 5 "R&D")	Undertake experimental research on tokamak plasmas with doublet and dee-shaped cross-sections in the Doublet III, a tokamak facility, located in LaJolla, California.

Country	Start Date End Date	Type of Agreement	Description
7. Japan	08/1979 05/1989	Project (under 5 "R&D")	Establish a Coordinating Committee on Fusion Energy to facilitate the coordination and implementation of cooperative activities in the area of fusion as well as to assure proper balance and to ensure the overall planning and oversight of such cooperative activities.
8. Japan EXPIRED?	02/1982 02/1987	Project (under 5 "R&D")	Agreement makes possible utilization by the Ministry of Education of one of the two test cells in the Rotating Target Neutron Source at Lawrence Livermore National Laboratory.
9. Japan	01/1983 05/1989	Project (under 5 "R&D")	A cooperative program for the exchange of information, personnel and equipment, and special activities as may be mutually agreed, in various technical areas between DOE and the Ministry of Education, the Science and Technology Agency, and the Ministry of International Trade and Industry, as established by an exchange of diplomatic notes and separate agreements with each organization.
10. Japan	11/1983 11/1988	Project (under 6 above)	Materials developed by JAERI along DOE materials, are irradiated in the Oak Ridge Research Reactor (ORR) and the High Flux Isotope Reactor (HFIR), and jointly analyzed.
11. Japan EXPIRED?	03/1984 03/1987	Project (under 6 above)	JAERI-build components are tested at Tritium System Test Assembly at the Los Alamos National Laboratory.

in the field of Magnetic Fusion Energy page 3

Country	Start Date End Date	Type of Agreement	Description
12. Japan	10/1984 10/1987	Project (under 6 above)	DOE and JAERI plan, conduct and evaluate joint blanket neutronics experiments in JAERI's Fusion Neutronics Source facility to provide experimental data to determine the accuracy, guide the development, and establish the validity, of computational methods and databases used in calculations for nuclear design of fusion reactor blankets.
13. Japan	11/1986 11/1988	Project (under 9 above)	Test at TSTA two process-ready components, the polladium diffuser, and the ceramic electrolysis cell, designed and manufactured by JAERI for the purpose of developing improved components for the fuel cleanup system which would be applicable to the next generation of fission experimental devices.
14. Japan	06/1987 06/1992	Project (under 10 above)	Objective is to define, conduct, and evaluate the joint operation and experiments on fusion fuel technology with the TSTA at LANL for the purposes of: developing and demonstrating fuel processing technology for fusion power systems; developing and testing environmental and personnel protective systems for tritium handling; developing, testing, and qualifying equipment and material for tritium service in the fusion energy program; operating systems that can become the basis for tritium systems for advanced fusion machines such as an ignition experiment, an engineering test facility, or a reactor; demonstrating reliability of components; and demonstrating safe handling of tritium.
15. Spain	12/1985 12/1988	Project (under 3 "S&T")	Cooperate in toroidal confinement devices collaborating on the selection of an optimal magnetic configuration for the TJ-II in Spain.
USSR		(under 9 "R&D")	

CURRENT ENERGY R&D BILATERAL AGREEMENTS AS OF JULY 1987
WITH UNITED STATES DEPARTMENT OF ENERGY INVOLVEMENT
in the field of

RENEWABLE ENERGY

Country	Start Date End Date	Type of Agreement	Description
1. EC	12/1982 none	Letter	Exchange of information on solar, i.e., thermal solar power stations; photovoltaic energy production, energy production from biomass.
2. Israel	06/1985 06/1990	Project (under 3 "R&D")	Continue contracts with entities in Israel in the following areas: ternary adamantine materials for low cost solar cells; high efficient thin film cadmium chalcogenide protoelectrochemical cell with in-situ storage; absorption heat pump simulation and studies; research on fabrication and characterization of amorphous silicon films and devices.
3. Israel	06/1985 06/1990	Project (under 3 "R&D")	Establish cooperation between institutions of the parties to advance understanding and use of absorption cycles and working fluids for solar cooling.
4. Israel	06/1985 06/1990	Project (under 3 "R&D")	Evaluate the state of the art of microalgal-biomass production; compare advanced algal biomass systems; compare alternative energy products of various systems; identify critical research needs in the field of algal biomass energy production and conversion systems.
5. Italy	06/1975 06/1990	Umbrella	Extending areas of collaboration in geothermal energy R&D to include hot dry rock and well simulation, brine utilization, resource assessment and reservoir physics and engineering; deep drilling exploration methodologies and environmental aspects.

in the field of Renewable Energy

Country	Start Date End Date	Type of Agreement	Description
6. Japan	06/1978 06/1988	Project (under 5 "R&D")	Establish a balanced exchange of geothermal energy application technology in areas such as new techniques for resource assessment; drilling and fracturing; volcanic studies; evaluation of reservoir life, etc.
7. Japan	09/1981 05/1989	Project (under 5 "R&D")	Establishes a personnel and information exchanges as well as some joint equipment developments, in research (biological, physical and chemical) in the area of solar energy conversion by means of photosynthesis.
8. Japan	05/1982 05/1989	Project (under 5 "R&D")	Establish a balanced exchange of solar energy technology in such areas of solar thermal power systems; photovoltaic power systems; solar heating and cooling and hot water supply systems.
9. Mexico	04/1986 04/1989	Umbrella	Achieve a thorough understanding of nature of geothermal reservoirs in sedimentary and fractured igneous rocks to investigate how the geothermal resources can best be explored and exploited and to exchange information on geothermal topics of mutual interest.
10. Saudi Arabia	02/1987 02/1992	Umbrella	Finding solutions to mutually agreed problems associated with renewable energy research and development and to exchanging information developed during resolution of these problems.
11. S.Korea	11/1981 11/1991	Umbrella	Foster cooperation in solar energy through an exchange of information, personnel and utilization of coordinators. (DOE/SERI)

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NUCLEAR ENERGY AGENCY (NEA) AGREEMENTS WITH U.S. DEPARTMENT OF ENERGY INVOLVEMENT

	Description	Dates
1.	International STRIPA Project (Phase I-III)	5/80 thru 9/91
2.	OECD Halden Reactor Project	6/58 thru 12/87
3.	International Sorption Information Retrieval System (ISIRS)	7/81 thru 7/87
4.	Program for Inspection of Steel Components (PISC-III)	4/85 thru 4/88
5.	Loss-of-Fluid Test (LOFT) Experimental Program	2/83 thru 9/89
6.	International Agreement on Decommissioning Information	9/85 thru 9/90

SUMMARY TABLE OF
COLLABORATIVE PROJECTS IN ENERGY RESEARCH, DEVELOPMENT AND DEMONSTRAT.

	Aus.	Aut.	Bel.	Can.	Den.	Ger.	Gre.	Ire.	Ita.	Jap.	Lux.	Nth.	NZ	Nor.	Por.	Spa.	Swe.	Swz.	Tur.	UK	USA.	EEC.	Duration
RGY END USE TECHNOLOGY																							
BUILDINGS AND COMMUNITY SYSTEMS																							
Energy Systems and Design of Communities						X	A		X												X		1979 1982
Residential Buildings Energy Analysis			X		X				X			X					A		X		X		1979-1983
Commercial Buildings Energy Analysis			X	X	X	X						X					X	X		A	X		1977 1980
Commercial Building Monitoring	X		X	X								X						X		A	X		1979 1983
Monitoring of Building Complexes						A															X		1976 1980
Windows and Fenestration			X			X			X			A		X				X		X	X*		1982-1986
Air Infiltration Centre*			X	X	X	X						X	X	X			X	X		A	X		1978 on-going
Minimum Ventilation Rates*				X	X	A			X			X					X	X		X	X	X	1980-1986
. .em Simulation*			A			X			X			X					X	X		X			1983-1986
Inhabitants' Behaviour - Ventilation			A			X						X						X		X			1984-1986
Energy Auditing			X	X					X			X		X			A	X		X	X	X	1983 1988
Energy Auditing in Hospitals			X	X		X			A								X	X			X		1985 1987
Local Government Energy Projects						X			X								X				A		1981 1985
DISTRICT HEATING*			X	X	X	X			X			X		X			A				X		1983 1986
HEAT PUMPS																							
Heat Pumps with Thermal Storage		A			X	X		X	X			X	X				X	X			X		1977-1980
Advanced Heat Pump Systems		X	X	X	X	A			X	X		X				X	X	X		X	X		1978-1980
Vertical Earth Heat Pump Systems		X		X	X												A				X		1981 1983
Heat Pump Systems Applied in Industry*		X	A	X	X			X	X	X		X					X						1981-1984
Large Heat Pumps for District Heating					A	X			X								X						1982-1985
High Temperature Working Fluids in Compressor Driven Heat Pumps*		A			X	X				X							A				X		1982 1985
Heat Pump Centre		X		X		A			X	X		X					X				X		1982-on-going
	Aus.	Aut.	Bel.	Can.	Den.	Ger.	Gre.	Ire.	Ita.	Jap.	Lux.	Nth.	NZ	Nor.	Por.	Spa.	Swe.	Swz.	Tur.	UK	USA.	EEC.	

	Aus	Aut	Bel	Can	Den	Ger	Gre	Ire	Ita	Jap	Lux	Nth	NZ	Nor	Por	Spa	Swe	Swz	Tur	UK	USA	EEC	Duration
ENERGY STORAGE																							
Large Scale Thermal Storage Systems			X		X	X						X					X	A			X	X	1979 1983
Lake Storage Demonstration at Mannheim					X	A						X					X				X		1979-1981
Aquifer Storage Plants					X	X						X					X	A			X	X	1978-1988
COMBUSTION PROCESSES																							
Combustion System Modelling				X					X	X				X			X			X	A		1977-1986
ENERGY CASCADING																							
Treble Rankine Cycle		X				A				X		X											1979-1984
HEAT TRANSFER																							
Heat Exchangers												X					X	X		A	X		1977-on-going
ENERGY CONSERVATION IN INDUSTRY																							
Cement Industry						X							X				X			X	A		1978 1983
Iron and Steel Industry*										X							A						1982-1983
Pulp and Paper Industry*		X	X	X	X					X		X	X	A		X	A			X	A		1981-on-going
AUTOMOTIVE ENGINES																							
Ceramics for Automotive Gas Turbine Engines						X											X				A		1979-on-going
Alcohol Blends as Motor Fuels				X						X			X				A				X		1984-1988
FOSSIL FUEL TECHNOLOGY																							
COAL																							
Coal Technology Information	X	X	X	X	X	X		X	X	X		X	X			X	X			A	X		1975-on-going
Treatment of Coal Gasifier Effluent Liquors												X								A	X		1976-1978
	Aus	Aut	Bel	Can	Den	Ger	Gre	Ire	Ita	Jap	Lux	Nth	NZ	Nor	Por	Spa	Swe	Swz	Tur	UK	USA	EEC	

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	Aus.	Aut.	Bel.	Can.	Den.	Ger.	Gre.	Ire.	Ita.	Jap.	Lux.	Nth.	NZ.	Nor.	Por.	Spa.	Swe.	Swz.	Tur.	UK.	USA.	EEC.	Duration
Dry Coal Feeding						A														X			1979-1982
Pressurised Fluidised Bed Combustion						X														A	X		1975-1985
Atmospheric Fluidised Bed Combustion				X	X				X	X		X	X	A			A	A					1980-on-going
Pyrolysis of Coal						X											A			X			1978-1987
Coal/Liquid Mixtures (CLM)				X					X	X		X				X	A			X	X		1981-1986
Low nitrogen Oxides Coal Burner				X	A												X				A	•	1980-on-going
Coal Combustion Sciences	X			X	X	X						X									A		1985-1988
International Conference on Coal Science																							
OIL																							
anced Oil Recovery**	X	X		X	X	A				X				X						X	X		1979-1986
NEWABLE ENERGY																							
GEOTHERMAL ENERGY																							
Geothermal Equipment Testing***									X				X								A		1979-1983
Man-made Geothermal Energy Systems						A				X							X	X		X	X		1977-1979
Energy from Hot Dry Rocks						X				X											A		1979-1986
SOLAR HEATING AND COOLING																							
Performance of Solar Heating and Cooling Systems			X		A	X			X	X		X				X	X	X		X	X		1977-1981
Co-ordination of Research and Development on Solar Heating and Cooling Components and Systems.		X	X		X		X		X	A		X		X		X	X				X		1977-1984
Performance Testing of Solar Collectors	X	X	X	X	X	X			X	X		X	X			X	X	X		A	X	X	1977-1987
Development of an Insolation Handbook nd Instrument Package			X	X		X			X			X				X		X		X	A	X	1977-1980
	Aus.	Aut.	Bel.	Can.	Den.	Ger.	Gre.	Ire.	Ita.	Jap.	Lux.	Nth.	NZ.	Nor.	Por.	Spa.	Swe.	Swz.	Tur.	UK.	USA.	EEC.	

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	Aus.	Aut.	Bel.	Can.	Den.	Ger.	Gre.	Ire.	Ita.	Jap.	Lux.	Nth.	NZ	Nor.	Por.	Spa.	Swe.	Swz.	Tur.	UK	USA	EEC.	Duration
Use of existing Meteorological Information for Solar Energy Application		X	X	X	X	X			X			X					A	X		X	X	X	1977 1982
Evacuated Tubular Collector Systems Performance	X			X		X				X		X					X	X		X	*A	X	1979 1987
Centralised Solar Heating Plants		X		X	X	X						X					A	X		X	X	X	1979 1988
Passive Low Energy Houses		X	X	X	X	X			X			X	X	X		X	X	X		X	A	X	[illegible] 1986
Passive and Hybrid Solar Commercial Buildings			X		X	X			X	X			X	X			X	A		X	X	X	[illegible] 1990
Solar Radiation and Pyranometry Studies		X		A	X	X			X	X		X		A			X	X			X		[illegible] 1986
Solar materials R&D		X		X	X	X			X	A		X					X	X			X		1985 1990
SMALL SOLAR POWER SYSTEMS		X	X			A	X		X							X	X	X		X	X		1977-on-going
BIOMASS CONVERSION																							
Technical Information Service*		X	X	X		X		A	X	X			X	X	X		X	X		X	X	X	1976 1986
Forestry Energy*		X	X	X	X			X					X	X			A				X		1978 1988
Peat Production and Utilisation*				X				X									A						1984-1988
OCEAN ENERGY																							
Wave Energy Conversion				X				X		A										X	X		1978-1984
Wave Energy Information								X		A				X			X			X	X		1985 1988
WIND ENERGY																							
Large Scale Wind Energy Conversion Systems				X	X	X						X					A			X	X		1977 on-going
Cooperative Studies on Wind Energy Conversion Systems		X		A	X	A		X		X		A	X	X			A	X		A	A		1977-1987
PRODUCTION OF HYDROGEN FROM WATER																							
Thermochemical Production			X	X		A			X	X		X						X			X	X	1977 1986
Electrolytic Production			X	X		X			X	X		X						X			A	X	1977 1986
Photocatalytic Production			A	X								X						X			X		1979 1986
Hydrogen Storage, Conversion and Safety				X		A				X							X	X			A		1981 1986
Future Markets for Hydrogen			X	X		X				X		X					X	X			X	A	1977 1980
	Aus.	Aut.	Bel.	Can.	Den.	Ger.	Gre.	Ire.	Ita.	Jap.	Lux.	Nth.	NZ	Nor.	Por.	Spa.	Swe.	Swz.	Tur.	UK	USA	EEC.	

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	Aus.	Aut.	Bel.	Can.	Den.	Ger.	Gre.	Ire.	Ita.	Jap.	Lux.	Nth.	NZ.	Nor.	Por.	Spa.	Swe.	Swi.	Tur.	UK.	USA.	EEC.	Duration.
ROLLED THERMONUCLEAR FUSION																							
PLASMA-WALL INTERACTION				X		A				X							X	X	X		X	X	1977-1992
SUPERCONDUCTING MAGNETS										X								X			A	X	1977-1987
RADIATION DAMAGE IN FUSION MATERIALS																							
Materials Irradiation Test Facility				X						X							X				A	X	1980-1985
Implementation on Radiation Damage in Materials				X						X							X	X			X	A	1980-1990
LARGE TOKAMAKS										A											X*	X	1986-1991
STELLARATOR DEVELOPMENT						A											X				X	X	1985-1990
PLASMA TECHNOLOGIES WITH POLOIDAL FIELD DIVERTORS						A											X				X	X	198[illegible]-1995
RGY TECHNOLOGY SYSTEMS ANALYSIS	A	X	X	X	X	X	X	X	X			X		X		X	X	X		X	A	X	1976-on-going
	Aus.	Aut.	Bel.	Can.	Den.	Ger.	Gre.	Ire.	Ita.	Jap.	Lux.	Nth.	NZ.	Nor.	Por.	Spa.	Swe.	Swi.	Tur.	UK.	USA.	EEC.	

Finland, a non-IEA country takes part in this project.
Egypt, a non-IEA country takes part in this project.
Mexico, a non-IEA country took part in this project.

X = Participating in Project
A = Operating Agent
X* = Former Participant

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APPENDIX G

It is the purpose of this Appendix to state the invention funding source lists in categories of "electable," "determinable," and "not electable". The mutually agreed listings are by B&R number or other designation as appropriate, such as IR&D. The object of these invention funding source lists is to facilitate technology transfer through ease and sureness of invention title passing to the University while at the same time protecting DOE's legitimate interests.

Classified inventions shall remain in the "not electable" category unless DOE and the University mutually agree otherwise for a particular case.

Findings of exceptional circumstances are under authority of 35 USC 202(a)(ii); findings of weapons related are under authority of 35 USC 202(a)(iv); and findings of naval nuclear propulsion are under authority of 35 USC 202(a)(iv).

Appendix G shall be subject to revision by mutual agreement of the parties. The Department reserves the right to advise the University of any endangerment to national security which may result from any action by the University in the exercise of its rights under Appendix G. In such event, the University agrees to refrain from such action until the national security issue is resolved by mutual agreement. The parties shall seek a mutual agreement as to the resolution of the national security issue involved within 90 days.

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APPENDIX G (CONTINUED)

Electable

Conservation

- AM Geothermal
- EA Solar
- EG Multi-Sector
- EE Transportation
- EC Building & Comm. Systems
- AK Electrical Energy
- AL Energy Storage Systems
- EB Solar Energy

ER

- HA-02 Environmental & Biological
- KE University Research Support
- AT Magnetic Fusion

Propulsion

- KA High Energy Physics
- KB Nuclear Physics
- KC Basic Energy Sciences
- KD Energy Research Analysis

Fossil E

- AA Coal
- AC Petroleum
- AB Gas
- SA Strategic Petroleum Rev.
- AX Liquid Gas Fuels

NE

- AH Remedial Action
- AF Nuclear Energy (Except Multi-Megawatt Space Reactor)

Determinable Not Automatically Electable

DOD and Intelligence Reimbursables

Director's IR&D Fund

Indirect Deparmental Research
- Chemistry Department
- Engineering Department
- Computations Department

Not Electable (Subject to Waiver)

DP

- AR Defense Waste
- GC Verification and Control
- GD Nuclear Safeguards and Security
- GE Materials Production
- GB Weapons Activities

NE

- CD Uranium Enrichment
- AF Nuclear Energy (Multi-MegawattSpace Reactor only)

WM

- DB Nuclear Waste Fund

Naval Nuclear

- AJ Naval Reactors

Classified Inventions

UCNI Inventions

APPENDIX G (CONTINUED)

Electable	Determinable Not Automatically Electable	Not Electable (Subject to Waiver)
Environmental Safety Health		
HA-01 R&D		
Mgt. & Adm.		
WB In-House Energy Mgt.		
Non-DOD, Non-Intelligence Reimbursables		
Indirectly funded work not otherwise designated as determinable		

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APPENDIX H

Electable Inventions pursuant to Clause 35, Paragraph (v)

1. S-64,752 entitled "Biological Particle Identification Apparatus", inventors: Gary Salzman, Charles Gregg, Kevin Grace and Richard Hiebert
2. S-63,209 entitled "Device for Simultaneous Measurement of Fluorescence from Individual Cells in a Large Number of Spectral Channels", inventors: Tudor Buican and John C. Martin

5. A copy of DOE patent waiver regulations is enclosed. These regulations provide authority for waivers generally, including class waivers. Proposed regulations establishing class waivers for the national laboratories (to the extent such laboratories do not already obtain patent rights pursuant to law) are internal agency documents which have not been approved for release.

QUESTIONS FOR HUMAN GENOME INITIATIVE HEARING
FROM SENATOR PETE WILSON
OCTOBER 5, 1987

(September 17, 1987 hearing before the Senate Energy Research and Development Subcommittee)

QUESTIONS FOR THE DEPARTMENT OF ENERGY:

1. The critics of "big science" as represented by the human genome initiative claim that major portions of the human genome will be uncovered in bits and pieces by laboratories operating in conventional ways. What is to be gained by the massive assault envisioned by the human genome initiative?

2. The Department of Energy recently named two research centers on the human genome? What is the function of a research center? How will the centers interact with both individual researchers and national laboratories such as LLNL, which is a major participant in this project? Are these going to function as administrative or scientific centers? How will they affect the level of funding currently going to such centers as LLNL?

3. The DOE recently directed Los Alamos National Laboratory and the Lawrence Berkeley Laboratory to establish centers to study the human genome. Since Lawrence LLNL has been in the forefront of researching the human genome, why was LBL, which currently has no facility for this research selected in place of LLNL which has a state of the art facility?

4. How will DOE ensure that there is parity between the various research centers so that they are not competing for the same resources at the federal level?

5. Would you elaborate on the DOE funding commitment to genome research in the past and what the forecast is for future funding?

1. The critics of "big science" as represented by the human genome initiative claim that major portions of the human genome will be uncovered in bits and pieces by laboratories operating in conventional ways. What is to be gained by the massive assault envisioned by the human genome initiative?

The objective of the human genome initiative is to create the technologies and resources which will allow an efficient characterization of the human genome at the molecular level. The initial goals are: 1) to greatly increase the speed and reduce the cost of sequencing and mapping, 2) to create a resource consisting of ordered cloned DNA fragments encompassing the entire genome, and 3) to create the database, networking and analytical resources necessary for widespread utilization of the new information and abilities.

It is true that mapping and sequencing of the human genome are being done in laboratories around the world. A very high percentage of this work is being done on the approximately 3,500 genes known to be related to genetic diseases. Yet there are an estimated 100,000 or so human genes. At the September 1987 Paris Workshop on Human Gene Mapping it was announced that 1,359 genes had been mapped to specific chromosomes and, in most cases, to specific subregions of chromosomes. Thus, today we have mapped only a small percentage of human genes. We have sequenced about one million bases of the three and a half billion bases which make up the human genome. Without an organized, comprehensive effort, it is hard to tell how long it would take to completely map and sequence the human genome. It has been estimated, based on current trends, it would take over 100 years to obtain the complete sequence of the human genome. With an accelerated effort the benefits of this knowledge can be obtained for the current generation. The present piecemeal approach requires much duplication of effort and utilizes inefficient technologies. The resources and technologies which will be developed in the initiative will allow mapping and sequencing to be done much more efficiently and rapidly than is the case today. The long-term results of this initiative will include a degree of sophistication in understanding human life that has never before even been approached and a significant strengthening of the technological foundations of the nation's biotechnology industry.

2. The Department of Energy recently named two research centers on the human genome. What is the function of a research center? How will the centers interact with both individual researchers and national laboratories such as LLNL, which is a major participant in this project? Are these going to function as administrative or scientific centers? How will they affect the level of funding currently going to such centers as LLNL?

It is likely that there will be different types and sizes of centers, with different functions. In its Report on the Human Genome Initiative the Department's Health and Environmental Research Advisory Committee said, "We envision three types of grants -- to individual investigators, to centers with 3 to 10 senior investigators, and to a few large centers that will include mapping, sequencing and interpreting the human genome." Centers (whether or not they have officially been designated as such by DOE) are likely to be located both at national laboratories and at universities. The Department's human genome research will be a coordinated effort in which all the involved researchers will be expected to cooperate. Individual scientists and centers will be connected through computer networks. While most centers will have a particular scientific focus, we anticipate that one center (to be designated later) will be assigned the responsibility for overall coordination and day-to-day administration. The level of funding for different elements of the effort will be determined by peer review of their scientific merit and evaluation of their contribution to the goals of the initiative.

3. The DOE recently directed Los Alamos National Laboratory and the Lawrence Berkeley Laboratory to establish centers to study the human genome. Since LLNL has been in the forefront of researching the human genome, why was LBL, which currently has no facility for this research selected in place of LLNL which has a state of the art facility?

The Lawrence Livermore National Laboratory plays a major role in DOE research on the human genome. We expect that LLNL will continue to do so and will be very successful in the competition for additional funds in this area. The Department believes that the Lawrence Berkeley Laboratory has great potential to make significant contributions to the human genome initiative. LBL, with its tradition of first-rate basic research and its close proximity to strong biological and other sciences at the UC Berkeley campus, can provide needed basic science support to the research effort and an opportunity for graduate students and post-doctoral associates to be trained in this developing area of science. The ultimate role that LBL and other institutions will play in this endeavor will depend upon their ability to organize appropriate staff to formulate and carry out research directed toward the goals of the initiative.

4. How will DOE ensure that there is parity between the various research centers so that they are not competing for the same resources at the federal level?

As noted in the previous answer, we expect that different institutions or centers will have different roles in this initiative, depending on their particular expertise or assignment and that the level of funding for each institution will be commensurate with its assignment. Thus, an institution which is preparing ordered, cloned DNA fragments from chromosome number one would have a much larger task than an institution preparing ordered, cloned DNA fragments from the much smaller chromosome number twenty-one.

One of the benefits of an organized, cooperative approach to these tasks, as DOE is proposing, is that undue duplication of effort can be prevented and resources can be utilized most effectively to accomplish the desired ends. A cooperative effort involving several centers will allow the testing of competing ideas, approaches and methodologies.

5. Would you elaborate on the DOE funding commitment to genome research in the past and what the forecast is for future funding?

The history of DOE's involvement in research on the human genome was provided in the answer to Senator Ford's question number 14. The human genome initiative proposed by DOE is, as mentioned above in the answer to question 1, aimed at creation of specific technologies and resources which will enable molecular level characterization of the human genome to proceed more effectively. DOE research aimed at these restricted goals, as distinct from its long-term interests in understanding the health effects associated with energy-related damage to genes, began in 1983 with the initiation of the National Laboratory Gene Library Project at Los Alamos and Livermore. The objective of this project is to prepare and separate the 24 types of human chromosomes and prepare cloned, DNA fragments from each type. These chromosomal-specific DNA "libraries" are made available to the scientific community through a repository funded by the National Insitutes of Health. Initial funding of this effort was around $800,000 per year and is now about $1.6 million. The human genome initiative is initiated in FY 1988 at a projected level of $12.9 million. In FY 1987 $4.7 million was devoted to projects aimed at the goals of the initiative, including the Gene Library Project and several new projects.

The Department's Health and Environmental Research Advisory Committee has recommended that the initiative be funded at a level of $20 million in FY 1988, $40 million in FY 1989, and increase by $40 million increments to a plateau level of $200 million from 1993 through 1995, at which time we should have the complete map of each chromosome, and an essentially complete sequence of at least one chromosome, along with a national capacity to sequence ten million bases per day. With the pressures on the national budget it is impossible to forecast future funding levels but it is anticipated that funding devoted to this initiative will increase over the next several years.

Los Alamos
Los Alamos National Laboratory
of the University of California
Los Alamos, New Mexico 87545

October 19, 1987

Senator Wendell H. Ford, Chairman
Subcommittee on Energy Research and Development
Senate Committee on Energy and Natural Resources
Washington, DC 20510-6150

Dear Senator Ford,

I wish to respond to the questions in your letter of September 30, 1987. These questions were a follow-up to the testimony given by myself and Warren F. Miller on September 15 and 17 on S. 1480, the "Department of Energy National Laboratory Cooperative Research Initiatives Act." The questions are related to superconductivity, the human genome initiative, and technology transfer.

1. Superconductivity

Since the development of high temperature superconductors is apparently a high priority item in many countries, to what extent should the U.S. participate or encourage international collaboration in R&D and commercialization? Is this approach the most effective way to tap the economic potential of high temperature superconductors?

International collaboration in research is imperative, especially in the field of superconductivity. Basic science should have no international borders. Our scientists continue to interact vigorously with scientists from other nations. We have benefitted greatly from visiting scientists from Europe and Japan. Although the United States still boasts the world's finest basic research program, other nations are playing a significant role in contributing to the world's knowledge pool. For example, the last three Nobel Prizes in Physics have gone to European researchers. That, of course, includes this year's winner T. G. Bednorz and K. A. Mueller for their work in the discovery of the new oxide superconductors. The Japanese are also mounting much more formidable research effort. Hence, we should not deprive ourselves of the fruits of international collaboration at a time when other nations have much to offer.

In areas of technology that have more immediate potential for commercialization we need to examine collaboration carefully and ensure that is is in the nation's best interest. Given that the President's Superconductivity Initiative reflects his belief that it is critical that the U.S. translate our leadership in science into leadership in commerce, we should assume that international collaboration benefits our national interest.

The President's Initiative provides some guidance in this area, specifically addressing collaboration with Japan. I quote from the July 28, 1987, White House Press Release, initiative component 11:

> Taking advantage of the opportunity presented by the current negotiations for renewing the U.S./Japan Agreement on Science and Technology to seek reciprocal U.S. opportunities to participate in Japanese government supported research and development, including superconductivity."

Emphasizing the word reciprocal, we should seek opportunities for collaboration that have clear benefit to the U.S. position. We should become hard bargainers when negotiating international collaborative R&D arrangements in the field of high temperature superconductivity.

This position is also consistent with the President's Executive Order 12,519 of April 10, 1987, Section 4, International Science and Technology, which states that the Head of each Executive department and agency, when negotiating or entering into cooperative research and development agreements and licensing arrangements with foreign persons or industrial organizations, shall, in consultation with the U.S. Trade Representative, give appropriate consideration to (among other things) whether such foreign companies or governments permit and encourage U.S. agencies, organization, or persons to enter into cooperative research and development agreements and licensing arrangements on a comparable basis (emphasis added.)

In summary, our position should be that the High Temperature Superconductivity Initiative expressly supports the U.S. competitive position. International collaboration in R&D and commercialization should be pursued only to the extent that such participation clearly benefits the U.S.

2. Human Genome Initiative

Has the U.S. anything to lose by investing in human genome research?

I believe that the U.S. has nothing to lose and much to gain by supporting the objectives enunciated in the Department of Energy's "The Human Genome Initiative." Dr. Warren F. Miller, Deputy Director of the Los Alamos National Laboratory, in his written testimony submitted for your Subcommittee noted that the "detailed understanding of the human genetic material is arguably the most important scientific challenge facing mankind." I agree with Dr. Miller. Knowledge of the human genome is an absolute requirement for examination of the genetic components of diseases among which number the major killers in the United State: cancer, cardiovascular disease, hypertension and stroke. Certainly, the Department of Energy's obligation to understand and assess the health effects of radiation and potentially harmful by-products of energy products of energy production and use cannot be adequately discharged in the absence of detailed knowledge of the human genome. The National Institutes of Health responsibilities for the study of human genetics and human disease will also be well served by the Initiative.

I would also like to reinforce Dr. Miller's comments on the Initiative's "deliverables," each of which is crucial to the scientific community as well as the private sector. These deliverables will be immediately available without the vexingwaiting periods so often associated with technological initiatives:

1. Ordered sets of recombinant DNA clones from individual human chromosomes will be made available as they are produced in the physical mapping component of the Initiative;
2. Computer-based data libraries for handling the vast amounts of generated data will guarantee access to the acquired information;
3. New biotechnologies will be available for commercialization by U.S. industry.

Are the Japanese as close as we are--or closer--to organizing this task?

We must assume that the Japanese are at least as close as we are to organizing the task, and I suspect that they may be ahead of us. Dr. Akioshi Wada of the University of Tokyo has initiated an automated DNA sequencing system developed as part of a program in 1981 to investigate automatic and high-speed DNA sequencing systems; the system will result in a ten-fold reduction of sequencing costs. One of the Department of Energy Initiative's prominent objectives is the development and subsequent commercialization of new mapping and sequencing technologies.

One must also assume that the Japanese have not been oblivious to the benefits of a program like the Human Genome Initiative. While they have cautiously described their effort as confined to the study of only one or two human chromosomes, it should be understood that no giant leap of technology is required for the Japanese to rescope their effort to include the entire human genome.

3. Technology Transfer

How does the current technology transfer program managed by the Energy Department affect research at Los Alamos and the flow of information between the laboratories and other research entities?

The current technology transfer program managed by DOE has little effect on the research programs at Los Alamos since these programs are essentially fully funded by the government. The primary reason for conducting research at Los Alamos is to support our programmatic mission and maintain a first-rate science and technology base. Spinoff from the research to private sector technologies, although encouraged in DOE policy statements, has been a secondary benefit.

Therein lies part of the problem of inadequate technology transfer. To effectively "transfer" technology to the private sector, the national laboratories must consider the market while conducting their R&D programs. Hence, industry must provide early input. Additionally, a continuous and vigorous interaction with industry must be maintained. I outlined what I believe the necessary steps are for successful technology transfer in my written statement at the September 15 hearing.

We have traditionally made the results of our research publicly available where possible, and we will continue to do so in the future. But mere transfer of information, such as we have historically done, does not in and of itself assure transfer of technology. It is clear from past experience that technology arising from programmatic research rarely is developed to the point that it can be commercialized. Commercialization almost always requires significant additional investment by the entity seeking to market the technology. Generally, the private sector seeks to obtain some form of exclusive right in the technology before it is prepared to make the investment necessary to commercialize it. Historically, DOE and its predecessor agencies were extremely reluctant to grant exclusive rights to government funded inventions made at Los Alamos.

We have found that the processing of patent waivers and licenses needs to be expedited greatly in DOE. Our current experience is that these take one year on the average, and that is a major barrier in transferring technology to industry. We need to create a "fast track" for technology transfer arrangements with approval authority delegated to the local DOE operations offices. The ability to process industry requests in a timely manner is crucial to the success of the technology transfer program.

The current DOE position with respect to the weapons laboratories appears to be one of seeking to assure that there is a free flow of information within the integrated contractor system. DOE operates on the premise that to grant exclusive rights in inventions arising out of the weapons program will be detrimental to this free flow of information. DOE also argues that granting exclusive rights in such inventions will result in an inherent conflict of interest between the need to protect security and classification and the desire to commercialize. We share some of DOE's concerns but believe that significant progress can be made on expediting licensing rights without jeopardizing classification or security. We intend to continue to develop a common understanding with DOE and create expedited procedures for technology transfer.

Secretary Herrington has asked the Los Alamos National Laboratory to assess industrial interest in national laboratory-industry partnerships. This may lead to a pilot program with industry in which new and novel methods may be explored to expedite the contracting and intellectual property rights issues. We hope that such pilot programs will make the laboratories more "user friendly" so that industry will aggresively pursue joint ventures with the laboratories.

I appreciate the opportunity to respond to your concerns.

Sincerely,

Siegfried S Hecker

Siegfried S. Hecker
Director

xc: CRM-4/A150
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NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICE OF THE
ASSISTANT DIRECTOR
FOR MATHEMATICAL AND
PHYSICAL SCIENCES

November 30, 1987

Honorable Pete Domenici
United States Senate
Washington, DC 20510

Dear Senator Domenici:

Enclosed are answers to questions you asked following the September 15 Subcommittee on Energy Research and Development's hearing on S. 1480. I appreciate having the opportunity to share with you the Foundation's views on superconductivity research.

If I can be of further assistance to you, please do not hesitate to contact me.

Sincerely,

Richard S. Nicholson
Assistant Director

QUESTIONS SUBMITTED BY SENATOR PETE V. DOMENICI

FOR THE NATIONAL SCIENCE FOUNDATION

1. There are a number of new information exchange initiatives designed to increase the flow of superconductivity information within the scientific community. These initiatives have ranged from scientific conferences, advisory groups, scientific clearing houses to computer accessible data bases, such as the one planned for Oakridge National Laboratory.

> How do you intend to ensure that information from these forums and data bases is not routinely available to our foreign competitors?
>
> Do you intend to monitor the access to these information sources to ensure that foreign competitors are not making more efficient use of the systems than their U.S. counterparts? We do not want to have U.S. tax payers sponsor Japan's basic R & D.

ANSWER:

For the most part the forums and databases to which you refer are not funded by the National Science Foundation and so we have little or no control over them. The problem you raise, however, is real and involves difficult tradeoffs.

In general, the NSF does not favor controls on otherwise open research or otherwise open scientific and technical communications. The freedom of such communication and collaboration in the United States has been an important source of our scientific and technical strength, extending at least to leadership in initial commercialization of new technologies. Immigrant scientists and engineers, who would presumably have to be excluded, have made tremendous contributions to our talent pool and to our science and technology. Paul Chu, for example, foremost important American contributor to date in superconductivity, came here as a student from Taiwan at the age of 22.

Further, erection of barriers against foreigners here would encourage erection of barriers against our scientists and engineers abroad. Such barriers could do us real harm. We have no monopoly of expertise in superconductivity or in many other technologies. As you know, the initial breakthrough in high-temperature superconductivity was made not by Americans, but by a Swiss and a German working in Switzerland. Open publication of this original research sped progress in this area.

The Japanese, in particular, are considered by our experts to be at least even with us in superconductor technology, so that we have much to learn from them. Nor have the Japanese created obvious barriers to such learning other than those inherent in their rather different research system. We are working to improve both U.S. access to Japanese laboratories and U.S. capability to take advantage of such access.

Preserving our competitive edge in a technology such as superconductivity may nonetheless sometimes be an overriding concern, particularly where technology research is jointly sponsored with industry.

2. U.S. industry has not been able to compete effectively in the international market, primarily because of our poor ability to translate scientific research efficiently into marketable products. Information exchange in itself is not sufficient to ensure timely product development in the superconductivity field.

> Since you do not support S.1480, what alternate approach would you propose to ensure that the U.S. is able to capitalize on its superconductivity breakthroughs?

ANSWER:

The Administration's proposals generally are contained in the President's Superconductivity Initiative. [Copy of Fact Sheet attached for the Record if not already included.]

For our part, the National Science Foundation has augmented support for research in high-temperature superconductivity programs at three materials research laboratories. We have also provided "quick start" grants for research on processing of superconducting materials into useful forms such as thin films, wires, and so on. If funding is provided as proposed by the President for NSF Science and Technology Centers, one or more of those Centers might well focus on superconductivity, though that will depend on proposals received and on review of proposals on their scientific and technical merits.

Incidentally, often the U.S. has been able to translate scientific research efficiently into marketable products, but then has faltered at retaining leadership in technologies it pioneered. We need to understand more clearly why that has happened and what can or should be done about it.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

November 12, 1987

Dear Senator Ford:

The responses for the September 15 and 17 testimony on S. 1480 "Department of Energy National Laboratory Cooperative Research Initiatives Act" are enclosed. We are glad that you found the testimony informative and hope you will find the answers to your and Senator Domenici's questions just as useful. I apologize for the delay in the transmittal and want to assure you that your further inquiries will be given prompt attention.

Thomas P. Rona
for William R. Graham
Director, Office of Science and
Technology

Senator Wendell H. Ford
Chairman, Subcommittee on
Energy Research and Development
Washington, D.C. 20510-6150

RESPONSES TO QUESTIONS FOLLOWING TESTIMONY ON S. 1480, SEPTEMBER 15 AND 17, 1987

QUESTIONS FROM SENATOR WENDELL H. FORD

SUPERCONDUCTIVITY

QUESTION: Since development of high temperature superconductors is apparently a high priority in many countries, to what extent should the U.S. participate or encourage international collaboration in R&D and commercialization? Is this approach the most effective way to tap the economic potential of high temperature superconductors?

ANSWER: Historically, the U.S. has been the major source of basic research disseminated in the public literature. A substantial portion of that research is government funded and performed in our universities and public research institutions. Often the products of the research have been utilized and commercialized by foreign corporations competing directly with U.S. business.

The U.S. science and technical community benefits to a much lesser extent from the findings of research performed and publicly disseminated in other countries. And, in some countries, a significant portion of government- sponsored research is performed within private companies, without public dissemination.

Despite this imbalance in costs and benefits from research, the U.S. government should continue to sponsor basic research (including that on superconductivity) in the public sector and with foreign collaboration so long as there is free, two-way dissemination of results. This is both appropriate and necessary to maintain involvement of our universities. However, at the point where the products of the research point clearly to potential commercial value, the options for commercialization should be retained for the benefit of the U.S. economic system.

(continued)

It was for related reasons that the Congress passed the Bayh-Dole Patent and Trademark Amendments of 1980 which gave nonprofit organizations and small businesses the right to inventions made under Federal grants and contracts. In 1984, the Congress passed legislation (Public Law 98-620) by which this policy was extended to include Federal laboratories operated by universities and nonprofit corporations. The Federal Technology Transfer Act of 1986 brought government-owned and operated Federal laboratories into the arena by authorizing participation with industries and universities in cooperative research and development programs, and allowing the labs to retain rights to, and to license, inventions made by their scientists.

As in the past, the government should continue to encourage public dissemination of the findings from basic research. We cannot build walls around our basic research efforts without becoming isolated from the rest of the scientific world in other countries. Yet, we must adequately protect our interest in new technology and the promise it holds for the U.S. industrial base. Providing for ownership of the intellectual property arising from research is an innovative way to encourage the universities and laboratories to reserve the commercial potential of the research for U.S. private industry, while responding to their traditional mission of conducting and reporting basic research.

QUESTION: The Administration has expressed concern that steps must be taken to prevent superconductivity technologies developed in the U.S. from being transferred to our foreign competitors. This concern was manifested by the decision to exclude foreign competitors from attending the recent Federal Conference on Superconductivity. Point 3 of the President's 11-point Superconductivity Initiative addresses this issue as well, recommending that Federal agencies be authorized to withhold commercially valuable scientific and technical information generated in government-owned and operated laboratories.

However, point 11 of the Initiative states: "Taking advantage of the opportunity presented by the current negotiations for renewing the U.S.-Japan Agreement on Science and Technology to seek reciprocal U.S. opportunities to participate in Japanese government-supported research and development, including superconductivity." How can these two provisions be compatible? Do you envision a reasonable balance between international cooperation and limiting the dissemination of U.S. developed technology?

ANSWER: There are several distinctions between points 3 and 11 of the President's Superconductivity Initiative. Regarding point 3, foreign countries currently have considerable access to U.S. government-sponsored research through the published literature and their student enrollment at our universities. Further, it can be assumed that the basic research sponsored by our government at our universities will continue to be accessible by these means in the future. The only research results that will be held back from early publication will be those relating to commercial applications.

Point 11 addresses the imbalance with the Japanese in sharing results from government-sponsored research. The Japanese government sponsors certain basic research within its industry, the results of which are not available to our scientists. The objective in negotiating the agreement is to obtain reciprocity--access in kind to their government-sponsored research. This implies access to their laboratories as they have to ours, and opportunities for exchange of scientists. In effect, we look for an agreement that involves sharing of the costs and risks of the research as well as the benefits.

HUMAN GENOME

QUESTION: If S. 1480, as amended, were to be passed and implemented, what role do you envision your office having in this initiative. Is this role satisfactory to you? If not, what do you propose?

ANSWER: Under the provisions of the proposed S. 1480, the Director of Office of Science and Technology Policy would be a member of the proposed "National Policy Board on the Human Genome under the chairmanship of the Secretary of Energy."

However, under the Director, OSTP there is established the Federal Coordinating Council for Science, Engineering, and Technology with a provision for establishing committees to consider problems and developments in fields of science, engineering, and technology affecting more than one Federal agency. We believe that issues of the human genome initiative can and should be dealt with best through the FCCSET mechanism and that no new legislation is required to achieve the objectives defined in S. 1480.

QUESTION: How did your Office respond to the report issued in April by the HERAC (Health and Environmental Research Advisory Committee) recommendation that the Energy Department take the lead in the human genome initiative? Have you seen this report? (This report was prepared for the Department and its members consisted of mainly scientists.)

ANSWER: Although OSTP has seen the HERAC report, it was not asked to provide comments.

QUESTIONS FROM SENATOR PETE V. DOMENICI

QUESTION: While NSF agrees with the goals of S. 1480 to make the U.S. more competitive and strengthening our cooperative research efforts, there does not appear to be agreement that S. 1480 is needed to accomplish these goals. However, we have repeatedly heard from private industry that efforts to transfer technologies with commercialization potential from the National Laboratories is a cumbersome, non-timely process.

How do you believe that the Federal Government can rectify this problem?

ANSWER: Historically, the process of technology transfer from the national laboratories to our private industry has been less than efficient. We believe that part of the problem was caused by the process which required corporate researchers to negotiate with researchers at our national labs initially and then to carry out an often extended second set of negotiations with the legal counsel at DoE. We believe that the President's Executive Order 12591 facilitating access to Science and Technology has taken a step toward streamlining this process. In this Executive Order, the President ordered Secretary of Energy John Herrington to:

"(1) delegate authority to its government-owned, government-operated Federal laboratories:

> "(a) to enter into cooperative research and development agreements with other Federal laboratories, State and local governments, universities, and the private sector; and
>
> "(b) to license, assign, or waive rights to intellectual property developed by the laboratory either under such cooperative research or development agreements and from within individual laboratories."

In addition, I am pleased to say that substantive efforts are already underway at a number of agencies and laboratories to achieve the President's goals. Within the Department of Commerce, the Executive Working Group of the Interagency Committee on Federal Laboratory Technology Transfer is currently working on model cooperative R&D agreements that can be used by the laboratories to achieve uniformity in the arrangements with the private sector. In the meantime, many laboratories are drafting their own agreements in order to permit early contacts with industries and universities.

In my written testimony of September 15, 1987, regarding S. 1480, I commended the intent of your proposed legislation to extend this authority to the DoE government-owned, contractor-operated Federal laboratories. In my response, however, I took issue with a process which would accomplish this change in a piecemeal fashion by concentrating only on particular topics or areas of research.

In Executive Order 12591, the President also ordered the Director of the OSTP to:

> "convene an Interagency Task Force comprised of the heads of representative agencies and the directors of representative Federal laboratories, or their designees, in order to identify and disseminate creative approaches to technology transfer from Federal laboratories."

The Task Force is to report to the President on the progress of and problems with technology transfer from Federal laboratories by April 10, 1988. The Task Force report will consider this issue among its other responsibilities.

QUESTION: In order to ensure that we are taking full advantage of the National Laboratories, resources that are already being funded with Federal dollars, S. 1480 proposes that these labs focus on enabling technologies and enter cooperative agreements with industry and universities.

Do you believe that we could make more efficient use of those resources by having them focus on enabling technologies and improving their interaction with industry, particularly at the early stages of research?

ANSWER: According to Executive Order 12591:

"The head of each Executive department and agency, to the extent permitted by law, shall encourage and facilitate collaboration among Federal laboratories, State and local governments, universities, and the private sector, particularly small business, in order to assist in the transfer of technology to the marketplace."

We believe that the process of technology sharing created through this Executive Order will allow U.S. industry and universities to enter into cooperative agreements which will make more efficient use of the resources of the national laboratories. Some of these resources have already been redirected toward "enabling technologies" in what we feel to be an appropriate fashion.

I would be concerned, however, if we were to seriously alter the missions of our national laboratories, such that they become "job shops" for industry. As stated in my testimony on S. 1480, while I favor the national laboratories becoming more involved in basic research that could benefit our industrial competitiveness, I am concerned that such activity not be at the expense of other mission requirements. The Executive Order gives authority to the laboratories to conduct fundamental research on enabling technologies.

QUESTION: We have heard frequently that there is a major concern being voiced by the smaller R&D firms and small businesses or universities, that they are being left out of many of the government's superconductivity initiatives. Can you explain how the President's superconductivity initiative takes this into account and ensures that small research and commercial organizations are included?

ANSWER: Point 6 of the Initiative urges all Federal agencies to implement quickly the steps outlined in Executive Order 12591: specifically transferring knowledge from the laboratories into the private sector, and encouraging Federal, university and industry cooperation in research. Out of similar concerns, the President had already incorporated considerations of small business directly in Executive Order 12591, "Facilitating Access to Science and Technology". The issues are addressed in Section 1, Part (a) which refers to ". . . collaboration among Federal laboratories, State and local governments, universities, and the private sector, particularly small business."

DEPARTMENT OF HEALTH & HUMAN SERVICES Public Health Service

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NOV 2 4 [illegible]

The Honorable Wendell H. Ford
Chairman
Subcommittee on Energy Research and Development
Committee on Energy and Natural Resources
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

This is in response to your questions following the September 17 hearing on S. 1480, Title II, Mapping the Human Genome. Thank you for the opportunity to expand on our earlier remarks.

1. How much of the research conducted at NIH, on the mapping and sequencing of the human genome, is being done at or in association with a National Laboratory? At Universities?

Answer:

In fiscal year 1987, we estimate that the National Institutes of Health (NIH) provided about $315 million for research and research training related to the characterization of complex genomes. Of this sum, almost $107 million supported research related to mapping and sequencing the human genome. During the same year, the NIH provided about $4 million for genomic research conducted by investigators associated with the Department of Energy (DOE) National Laboratory system.

Almost $47 million, or about 15 percent of NIH-supported research was conducted in the NIH intramural laboratories. The remaining $264 million were spent on research and research training carried out in university- or industry-based laboratories.

In addition, the NIH contributed $3.4 million in support of GenBank®, the nucleic acid sequence database that is located at Los Alamos National Laboratory. There are additional arrangements whereby NIH contributes to the support of research resources that are shared by DOE- and NIH-funded scientists working on genomic analysis, such as the National Flow Cytometry and Sorting Resource funded by the NIH Division of Research Resources.

2. S. 1480 proposes creating a National Policy Board--how would this Board differ from the Domestic Policy Council Subcommittee mentioned in our testimony?

Answer:

As described in S. 1480, the National Policy Board differs from the Domestic Policy Council (DPC), Working Group on Biotechnology, Subcommittee on the Human Genome in three major ways:

A. The Subcommittee on the Human Genome has representation from the major Executive agencies involved in activities related to the human genome. These agencies are the National Institutes of Health, Department of Health and Human Services; the Office of Energy Research, DOE; the Directorate for Biological, Behavioral, and Social Sciences, National Science Foundation; and the Department of Agriculture. Representatives of the Food and Drug Administration, the Environmental Protection Agency, and the Office of Management and Budget also attend Subcommittee meetings in order to exchange essential information. The strength of this Subcommittee is that it is not situated in one agency, thus fostering a collegial atmosphere. In contrast, as described in S. 1480, the National Policy Board would be located in the Department of Energy.

B. When the Subcommittee on the Human Genome was established, the Director, NIH, was appointed Subcommittee Chairman. Under S. 1480, the proposed National Policy Board would be chaired by the Secretary of Energy.

C. Currently, the Subcommittee does not include university or industry representatives, as proposed under S. 1480.

At the September 17 hearing, I suggested that the DPC Subcommittee be enlarged to include four university representatives and four industry representatives. I believe that functions of the National Policy Board as outlined in S. 1480 are laudable, and that those objectives might be achieved by the above modifications to the Subcommittee membership.

3. How much do you estimate this project will cost, until actual mapping is completed? How much more will be needed to begin sequencing?

Answer:

As you are aware, these questions have been discussed on numerous occasions by many of the experts involved with advancing molecular genetics technology. Last August, the Office of Technology Assessment (OTA) sponsored a workshop on the costs of the human genome projects. Dr. Ruth Kirschstein, Director, National Institute of General Medical

Sciences, and NIH staff participated in efforts to estimate the costs associated with several components of genomic analysis. A short summary of that workshop prepared by OTA is enclosed. It is important to note, however, that the figures contained therein are subject to update and revision as our needs become more refined. For example, the broad range of some of the estimates indicates the current uncertainty regarding the costs of developing certain technologies. Furthermore, once certain tools have been obtained, such as improved cloning vectors or more highly specific restriction enzymes, future costs of genetic and physical mapping may be significantly reduced.

Similarly, advances in automated DNA processing will have a major impact in decreasing the cost of DNA sequencing. Recently, the popular press and the scientific literature have reported the approximate locations of many genes responsible for inherited disorders such as Huntington's disease, Duchenne muscular dystrophy, cystic fibrosis, and Alzheimer's disease. In each case, the actual sequence of nucleotide bases, the DNA building blocks, was determined by using a slow, labor-intensive technique. This is the standard methodology unless the laboratory doing the studies has access to a recently developed and marketed automated DNA sequencing machine. Such a machine is still in a relatively primitive stage of development and will need many refinements in order to make exhaustive sequencing of the entire human genome financially feasible. In fact, it is reasonable to assume that, in the near future, there will be many fundamentally different approaches to purifying and characterizing DNA, specific genes, and specific chromosomes. Until several such methods have been developed and compared, manual DNA sequencing will continue to be used to study genes of biological interest. To encourage the development of new methodologies, instrumentation, and analytical capability to accomplish such studies more efficiently and rapidly, NIH issued two program announcements on May 29, 1987, requesting researchers to submit grant applications in these areas. More recently, the National Institute of General Medical Sciences published a Request for Applications to promote research more specifically directed toward overcoming the barriers to characterizing complex genomes.

I would like to thank you for providing NIH with the opportunity to describe our activities related to the analysis of complex genomes and to discuss the pending legislation. Your efforts to highlight and to promote recent advances in this important area of human health research are to be commended. If I can be of further assistance, please do not hesitate to ask.

Sincerely yours,

James B Wyngaarden

James B. Wyngaarden, M.D.
Director

Enclosure

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JOHN H. GIBBONS
DIRECTOR

Congress of the United States
OFFICE OF TECHNOLOGY ASSESSMENT
WASHINGTON, DC 20510-8025

Dear

This letter is a followup to the OTA workshop on costs of human genome projects. At that workshop, there was apparent consensus on rough estimated costs of several components, and confusion or disagreement about many others. This letter is an attempt to confirm estimates made at the workshop, and in some cases to extend beyond those initial estimates. Our requests from Congress asked for information on costs of the projects, and I want to be careful in emphasizing the consensus on genetic and physical mapping and the substantial uncertainty about sequencing strategies. This letter is a solicitation of your advice. I will be writing the cost sections over the next month, and would therefore appreciate receiving your comments before October 23.

A short summary of the components is noted below, with the range of figures noted. These are summarized in the attached table.

- genetic maps based on VNTR and RFLP methods, with a factor of uncertainty due to disagreement about the need to go from 5 centimorgans to 1 centimorgan (this will be dealt with as a two-option estimate, with differences beginning 2 years out) [$7.5 million per year - 2 years for 5 cM to 5 years for 1 cM];

- physical maps consisting of ordered clones made in both cosmids (analogous to current yeast and nematode projects) and yeast artificial chromosomes (with this latter more tentative, but also rather low in cost) [$10 to 20 million per year for 5 years, including repository costs]

- computer facilities and data analysis (of map and sequence data available in databases) with two possible cost options: one based on specifying hardware and personnel and the other option to be calculated by adding 10-15 percent to the aggregate cost of all human genome projects [fixed option $12 million per year, or 10-15 percent of total budget (a much lower figure for first years)];

- technology development to improve and automate cloning, DNA handling, mapping, and sequencing steps. A figure of $500 million total was mentioned at the workshop, and there was some agreement about adding up the budget for other components and adding 25 percent. I got five or six letters that expressed concern that the proportional method would seriously understate these costs, and have gone back to the discussion to try to come up with a better approach. If the $500 million figure were used, it would overwhelm the production costs of the maps even if spread over many years. I therefore finally settled rather arbitrarily on figures of $20 million per year for early years, or 25 percent of total budget.

- training of personnel in shortage areas (e.g., computer/molecular biology dual expertise, organic chemistry/molecular biology dual expertise, bioengineering, physician/molecular biology dual expertise, technicians, sabattical training for those in one field interested in learning about related fields - molecular biology to computing, engineering to molecular biology, etc.) and workshops among participating groups to account for 10-15 percent of budget [25-50 people per year; 2 national symposia per year; 6 workshops per year - estimated $3 million per year or 10-15 percent of total budget for OTA projections];
- administrative costs of 1-2 percent, and 3-5 percent for planning and quality control (to pay for the national advisory board function and operation of quality control facilities that would monitor and set standards for cloning, mapping, and sequencing technologies) [will use $2 million base first year, with increments of $1 million for years 2-5, stabilizing thereafter.

There is little consensus on the crucial issue of sequencing - which is the largest single cost item, but also would not begin in most schemes until a couple of years from now. The debate about sequencing is really a compound disagreement about the costs of sequencing per base pair, the amount of redundancy necessary to make a sequence useful, and how much DNA would be sequenced as part of the project. I plan to handle this in my text by noting the wide disparity of calculated costs per base pair now, noting some agreement that costs would drop to $.20 per base pair in the next few years, and that decisions about sequencing cannot be made now, but could be much better judged in two years by the national advisory panel (whatever its precise nature). Such judgments would presumably be based on costs, on the availability of material to sequence (e.g., the degree of completeness of physical maps), and some consensus on priority regions to sequence. For projections of the first two years' budget, sequencing would be folded into technology development costs. For years three to five, it would be based on sequencing one small chromosome per year at $.20 per base pair ($30 million per year, based on 3-fold redundancy and 50 megabases per year). This estimate is for purposes of budgeting only, however, and could prove wildly high or low. If the technologies for cloning, preparing DNA for sequencing, and finally determining a DNA sequence become significantly cheaper, as some predicted at the workshop, this would be taken into account by increasing the amount of DNA sequenced at that cost. If costs remain too high, then only a fixed amount of sequencing would be done, and priorities would have to set by the oversight board. For years 6 through 10, I have arbitrarily assumed a doubling of the sequencing budget.

In addition to the components already noted, there may be several activities that would make genetic maps, physical maps, and sequence data more useful. At the workshop, Dr. Berg mentioned the utility of having a set of cDNA clones mapped to the physical and genetic maps. Victor McKusick has likewise noted the high utility of such an enterprise in directing sequencing and making the maps more readily amenable to finding genes in the clones associated with the physical maps, and also in setting priorities for sequencing. The idea seems to be that cDNAs libraries from different tissues and different developmental stages would be constructed (perhaps using subtractive hybridization to select for rare, developmental stage-specific, or tissue-specific mRNAs). Alternatively, this might involve only cataloging and centralizing access to existing cDNA libraries (as many have already been created by different laboratories). The cDNA maps would in turn be linked to the physical and genetic maps. I am interested in any refined estimates of the possible repository needs, costs of making such libraries, and costs of linking them to the maps.

There may well be other component projects that would make data from the genetic and physical maps more readily useful. This might include funds for collecting human pedigree resources, converting tissue samples to cell lines, or other "generic" services. As an example, a standard set of RFLP or VNTR markers would be quite useful for initial screening to roughly locate a gene under study in a new pedigree. CEPH plans to make such a mapping "kit" available. Perhaps similar resources should be built into human genome projects. I am open to any suggestions. I have added a $2 million per year line item years 1-5 to cover such costs, but this may be too much or too little.

Please let me know your response to the approach outlined above before October 23. Thank you.

Sincerely,

Robert Cook-Deegan
Senior Associate

Encl: Table of projected costs

BUDGET PROJECTIONS
($ million, adjusted to 1987)

	Year 1	Year 2	Year 3	Year 4	Year 5	Years 6-10	beyond
Genetic map	7.5	7.5	(7.5)‡	(7.5)‡	(7.5)‡	-----	-----
Physical map	15	15	15	15	15	5	-----
Computers and analysis	12*	12*	12*	12*	12*	12*	12*
Technology development	20¶	20¶	20¶	20¶	20¶	-----	-----
Training	3	3	3	3	3	3	-----
Administrative and quality control	2	3	4	5	6	6	10
Sequencing	-	-	30	30§	30§	60§	??
Related projects	2	2	2	2	2	-----	-----
Yearly totals	61.5	62.5	86 (93.5)	87 (94.5)	88 (95.5)	86	22+

‡ for 1 centimorgan map
to include repository costs

* or 10-15 percent of total budget; out-year projections include database maintenance, early years include purchase of hardware

¶ or 25 percent of total budget

§ subject to considerable uncertainty, depending on strategy and costs

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CORPORATE OFFICE
SCIENCE AND TECHNOLOGY

ONE JOHNSON & JOHNSON PLAZA
NEW BRUNSWICK, N.J. 08933

October 14, 1987

Senator Wendell H. Ford
United States Senate
Committee on Energy and Natural Resources
Washington, D.C. 20510-6150

Dear Senator Ford:

Thank you for your letter of September 28. I regret I am just now responding to your questions, but I returned to the office only yesterday from a trip overseas. Following are my answers:

DO YOU ENVISION THE GENOME RESEARCH PROJECT TO BE RESEARCH OF THE TRADITIONAL MODE, OR IS IT SOMETHING QUITE NEW THAT MERITS A NEW APPROACH?

The genome project is not research of the traditional mode. Nothing needs to be discovered for this project to move forward. It is more a project in drawing together that which is already known and melding it into a cohesive activity. The actual project is more like a manufacturing program than a research program. There will be several sites where automated instruments will be churning out bits and pieces of DNA on a 24 hour basis, the information analyzed, and entered in the computer where it can be archived, analyzed, stored and retrieved. The only creative elements in the project involve the upgrading of automated DNA sequencers and the development of computational algorithms which will apply particularly to this project.

YOU HAVE SAID THAT U.S. INDUSTRIES SHOULD BE THE PRIMARY BENEFICIARIES OF THE PRODUCTS OF GENOME RESEARCH, WHAT ABOUT FOREIGN COMPANIES THAT HAVE U.S. SUBSIDIARIES -- SHOULD THOSE SUBSIDIARIES BE TREATED AS OTHER U.S. FIRMS WOULD BE?

It is envisioned that this program will be funded by the taxpayers of the U.S. As such. the benefits should accrue to the taxpayers of the U.S. The fact that foreign companies have U.S. subsidiaries does not entitle them to free access to U.S. supported research. Johnson & Johnson has 165 divisions -- most of which are overseas. Though we contribute to the economy of those countries, in no instance has that given us a right to research funded and developed by the local governments.

MUCH OF THE RAW DATA CURRENTLY BEING PRODUCED BY GENOME RESEARCH CAN BE ACCESSED BY ANYONE WHO WANTS TO BUY INTO THE DATA BASES. GIVEN THAT THIS PROJECT SHOULD BENEFIT U.S. INDUSTRIES PRIMARILY, TO WHAT EXTENT IS IT POSSIBLE TO RESTRICT GENOME RESEARCH PRODUCTS, SUCH AS THE DATA BASES, TO U.S. INDUSTRIES?

I am not at all sure that it is possible or necessarily appropriate to restrict genome research information to U.S. industries. I have no problem sharing the information with researchers in other countries. I would hope, however, that the U.S. industries -- and universities -- would have first access to the information in order that we can be certain our research and commercial programs do not take second place to those overseas.

My concern is not so much whether the material will be made available to researchers, as whether the products of that research are commercialized overseas in advance of U.S. industries. To that purpose, I would like to stress that what can be protected through patents or copyright should be protected under this program, otherwise some other country will do so, thus robbing us of the chance to develop it. A portion of the technology, materials, instruments and devices developed during this program almost certainly can be protected by patent applications. I am less certain about our ability to protect the DNA; but, if we can, we should. I expect it would be difficult to protect it by patent application, but it may be achieved by copyright. The decision about whether to release the DNA to the scientific community can be made after we have protected it.

WHAT, IF ANY, ARE SOME OF THE FRUSTRATIONS FELT IN THE INDUSTRIAL ARENA CONCERNING THIS HUMAN GENOME INITIATIVE?

To date, by far the majority of the companies in the pharmaceutical and biotech industry have not been consulted regarding their interest in being involved in the planning or the participation of the human genome project. Discussions have moved through academia and the national labs with little or no consultation with industry. We are concerned that the information will slip into the hands of our competitors without being protected by patent or copyright, in which instance we would have funded the demise of several companies.

DOES THIS AREA OPEN UP COUNTLESS POSSIBILITIES FOR INDUSTRY?

It appears that the group that first gets access to the information contained in the human genome will be in a position to dominate the pharmaceutical and biotechnology industries for decades to come. At the present time, the pharmaceutical industry is one of the major commercial exporters in the U.S. If we lose that advantage, it could have a damaging effect on our balance of payments. The commercial applications in the area of pharmacology and biotechnology are practically unlimited. It appears that the answer to every disease known to mankind lies in the knowledge gained from knowing the mapping and sequencing of the DNA of the human genome.

WHAT ROLE DO YOU SEE SMALL BUSINESSES PLAYING IN THE PROPOSED CONSORTIA?

Small biotech and pharmaceutical companies will probably take the lead commercializing products from the knowledge gained by mapping and sequencing the human genome. Several of them are immersed in this technology already and are small, adaptable, and agile enough to take advantage of their position. If they get first access to the data, it could be the makings of several large companies. On the other hand, if foreign competition first gets access to it, it could mean the demise of several of our more promising companies.

ACCORDING TO MOST OF THE TESTIMONY I HEARD ON THURSDAY, IT SEEMS AS IF THE HUMAN GENOME PROJECT IS A SURE THING AND THAT ANY OR ALL RESULTING INFORMATION WILL BE SIGNIFICANT, TO SAY THE LEAST.

. HAS THE U.S. ANYTHING TO LOSE BY INVESTING IN THIS RESEARCH?

. The U.S. has absolutely nothing to lose in investing in this research and an enormous amount to gain. Commercially, we expand severalfold the opportunities in the biotech and pharmaceutical industries. On a deeper level, however, we can provide the lead in eliminating diseases that have plagued mankind for centuries and allow all citizens of the world to live out their full, expected life span in good health and die over a very narrow age range.

. ARE THE JAPANESE AS CLOSE AS WE ARE -- OR CLOSER -- TO ORGANIZING THIS TASK?

. The Japanese are in advance of us at this stage. They understand the opportunity and have quietly made a commitment to capture the lead. Unless we move swiftly, they will grasp the lead never to relinquish it. The results of that, by any measure, could be devastating.

Thank you for seeking my input to the above questions. I hope the answers are sufficiently clear. If I can clarify them further or if I can be of additional help, please know I stand ready to assist.

Sincerely yours,

Jack B. McConnell, M.D.

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Corporate Director
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